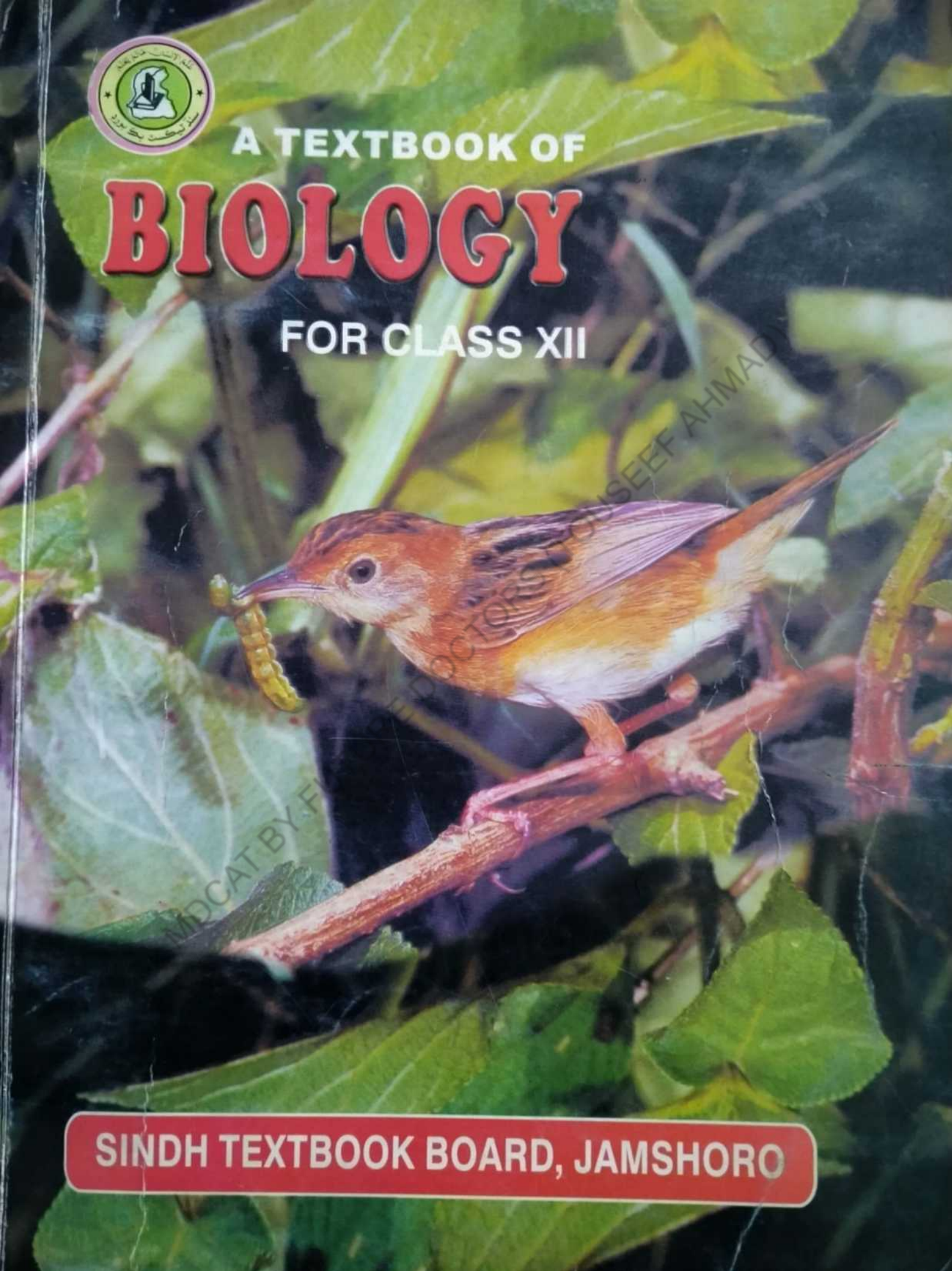

A TEXTBOOK OF BIOLOGY

FOR CLASS XII

SINDH TEXTBOOK BOARD, JAMSHORO

THE TEXTBOOK OF

BIOLOGY

FOR CLASS XII

SINDH TEXTBOOK BOARD
JAMSHORO

PUBLISHED BY
URDU ACADEMY SINDH
KARACHI

CONTENTS

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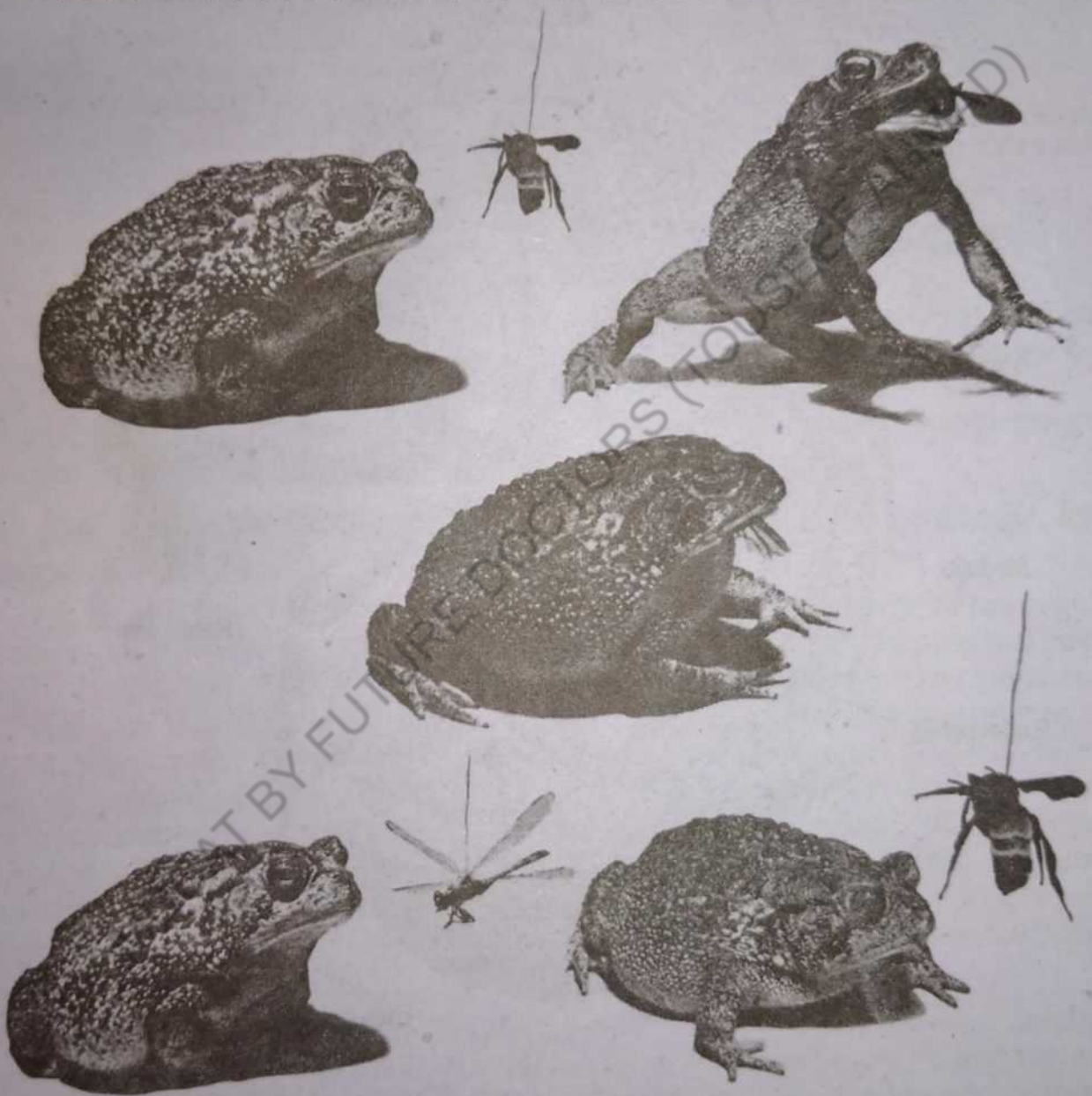
SECTION-I

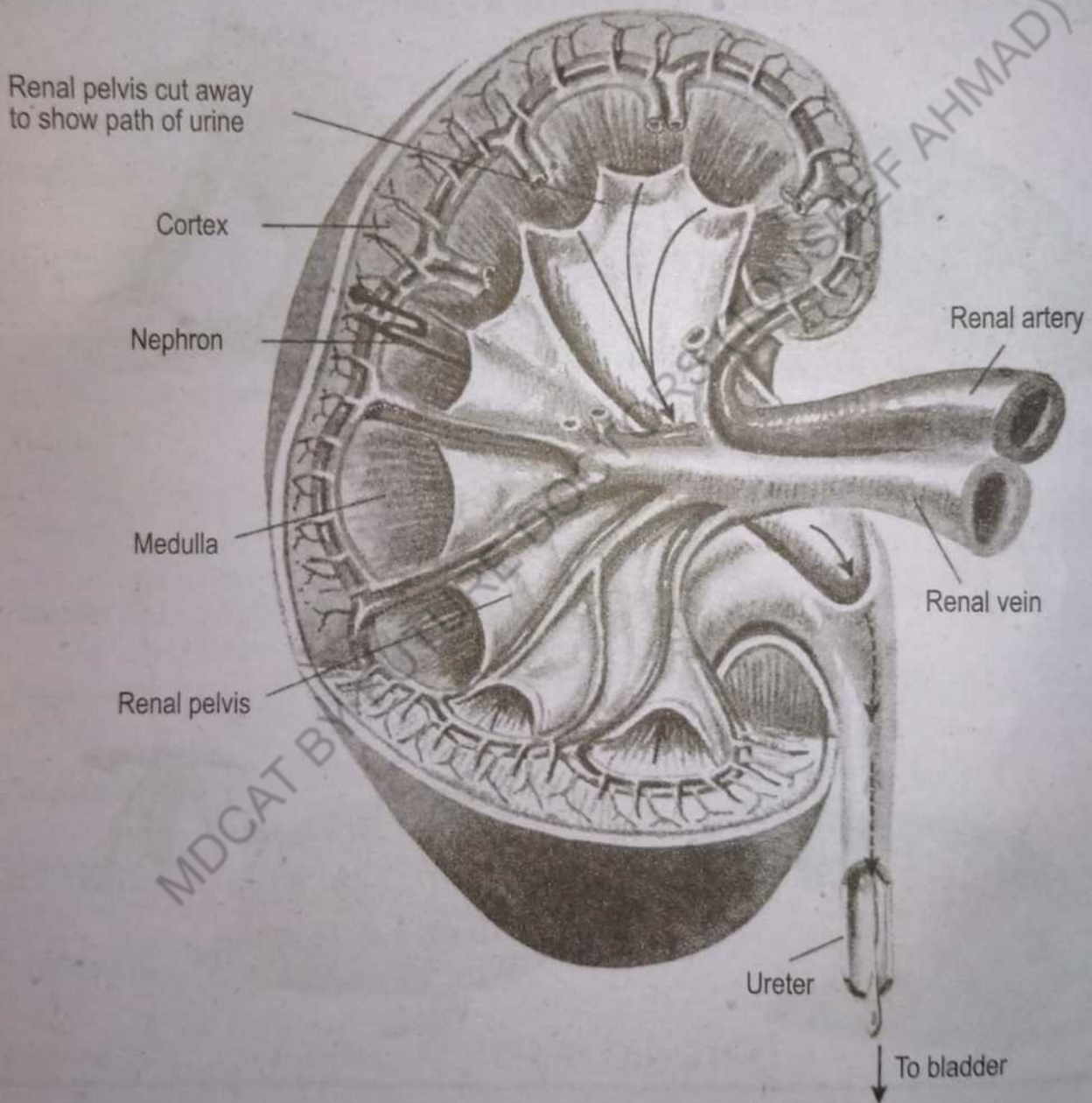
FUNCTIONAL BIOLOGY



Whenever you study life you come across a great diversity in form of organisms. They, of course, live in a variety of environments. They have most of their body functions in common. All organisms support locomotion, reproduce, grow and develop, they also maintain homeostasis. The body of all organisms is made up of various systems performing their own specialized functions but none of the systems operate without assistance from others.

CHAPTER 1

HOMEOSTASIS



All organisms must maintain a constant internal fluid environment to survive under varying external conditions. Thus during evolution of great variety of forms of living organisms, diverse mechanisms for maintaining homeostasis have been evolved.

1.1 HOMEOSTASIS AND ITS VARIOUS ASPECTS

The external environment or the conditions in which an organism lives may vary greatly even over a brief period of time. Temperature, acidity, salts, water, etc are some of the external factors to which an organism must adjust in order to survive. Meanwhile, each organism carries out certain activities, basic to life processes such as nutrition, respiration, etc which may produce some unwanted chemicals. Thus organisms, in order to live, have to maintain a steady internal environment to face the harsh fluctuating external conditions. Biologists term the maintenance of a steady state as homeostasis (Gr. to stay the same). It is defined as a set of regulatory mechanisms, which are involved in maintaining an organisms internal environment within suitable limits. The word environment refers to the conditions in which an organism lives. Thus the pond water inhabited by an Amoeba is its environment. Similarly, tissue fluid and sap are the environments of higher animals and plants, respectively. From the tissue fluids, cells not only receive all the substances they need, but also release into it their unwanted substances. Since the chemical composition of the tissue fluids is always subject to change, it must be kept constant or at least held at narrow limits if the cells continue to perform their vital activities.

The important aspects of internal environment that must be kept constant are **osmoregulation** (regulation of osmotic pressure of cell determined by the relative concentration of solutes and water); **excretion** (removal of excess substances, unwanted or toxic metabolic by-products); and **thermoregulation** (regulation of temperature up to a tolerable limit).

Need for regulating internal environment and control systems (concept of feed back):

There are number of mechanisms operating in the body of an organism to maintain homeostasis. Majority of such mechanisms are physiological processes. Logically, homeostasis requires a check and balance mechanism operating in the body. This check and balance mechanism is termed as **feedback system**. As soon as any change in any substance of internal environment takes place, it is detected, usually by special organs called **receptors** and immediately reported to a control centre (e.g. brain in case of higher animals), which decides about appropriate response and consequently it sends its instructions accordingly to some other organ called **effector**, which could play its role in bringing the target substance back to normal. It has been observed that there could be negative as well as positive feed backs.

Negative feed back refers to opposite effect produced in relation to any change in the body fluids. For example, as a consequence of eating sweets or candies the level of glucose is raised in the blood. It triggers the mechanism, which decreases the blood glucose back to normal limit. On the contrary, **positive feedback** refers to the series of similar effects produced, which leads to the enhancement of the change under consideration. For instance, in case of temperature regulation in warm blooded animals, increase in body temperature (e.g. in heat stroke) leads to further increase in temperature rather than decreasing it. Although, it seems harmful, in many cases it is useful.

1.2 OSMOREGULATION

Osmoregulation is one of the important aspects of homeostasis. It involves maintaining a balance between water and solute contents of cells.

1.2.1 Water Relations of Cell:

Water is used as biological solvent, which drives most of the metabolic activities of a living cell. It moves in and out of the cell by a process called **osmosis**. It is a special kind of diffusion in which water molecules move from higher concentration towards lower concentration across the plasma membrane.

1.2.2 Balance of water and solutes in the body:

Thermodynamically speaking, the potential energy of water in the region of its higher concentration is greater than its potential energy in the region of lower concentration. The potential energy of water molecule can be termed as **water potential**. Generally, it can be defined as the capacity of a living system to lose water. The concentration of a solution is biologically expressed either as water potential (in case of plants) or **osmotic pressure** (in case of animals) which shows relative amount of water and solutes in a cell.

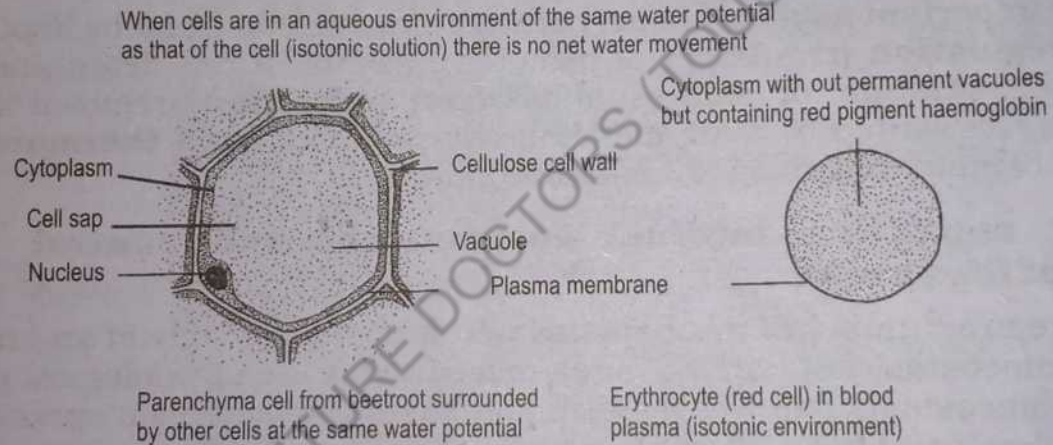


Fig 1.1(a) When the external water potential and that of the cell are the same...

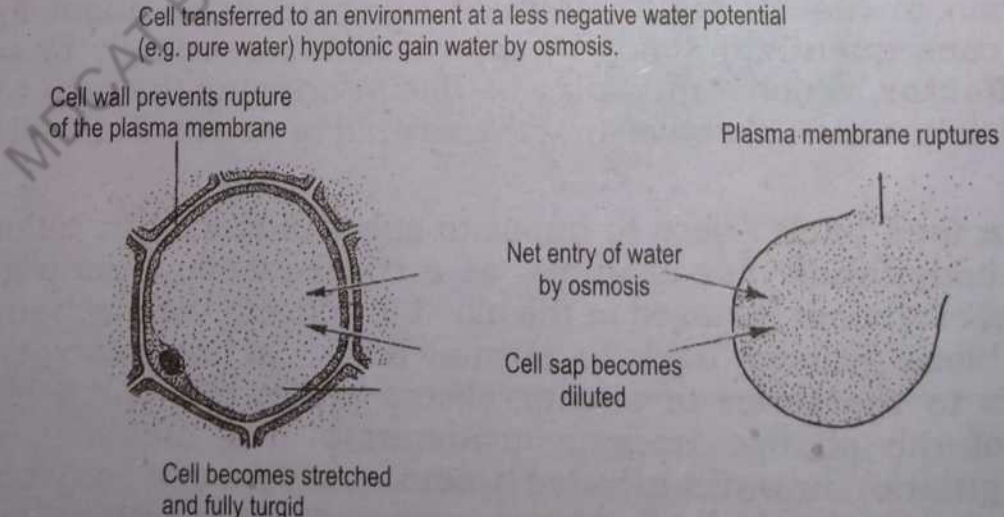


Fig 1.1(b) When the external water potential is less negative than the water potential of the cell

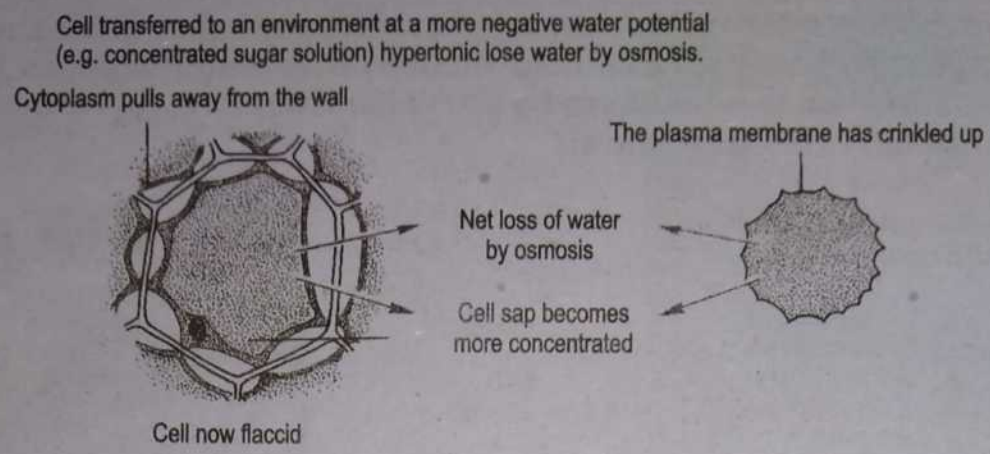


Fig 1.1(c) When the external water potential is more negative than the water potential of the cell

In case of plant cells, the water potential of cell sap (solution in vacuole) is termed as **solute potential**. If a plant cell is placed in pure water or solution of higher water potential than the solution in its vacuole, the water moves from outside to inside the cell (endosmosis) and ultimately into the vacuole. As a result, the cell swells or becomes turgid. Such an external solution is called **hypotonic**. Further allowing the cell into such hypotonic medium does not cause it to burst because the cell wall develops a tension causing an internal hydrostatic pressure or pressure potential due to which further uptake of water in cytoplasm is resisted and finally stops. On the contrary, if some animal cell is continuously placed in hypotonic solution, it bursts because the plasma membrane cannot resist the pressure potential. Thus within the bodies of higher animals, the tissue fluid is maintained at the same water potential, called **isotonic**, as the cell solution.

When a plant cell is placed in concentrated solution or **hypertonic** solution, there is a net movement of water out of the cell. As a result, the cell becomes flaccid. Under such condition, the cytoplasm with its plasma membrane shrinks from the cell wall. This condition is called **plasmolysis**.

1.2.3 Osmoregulation in Plants:

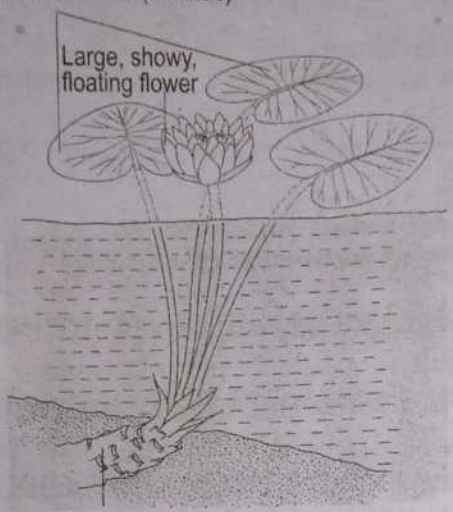
Depending upon the availability of water to flowering plants in their natural habitat, they are grouped into four categories:

i) Hydrophytes, ii) Halophytes, iii) Mesophytes and iv) Xerophytes.

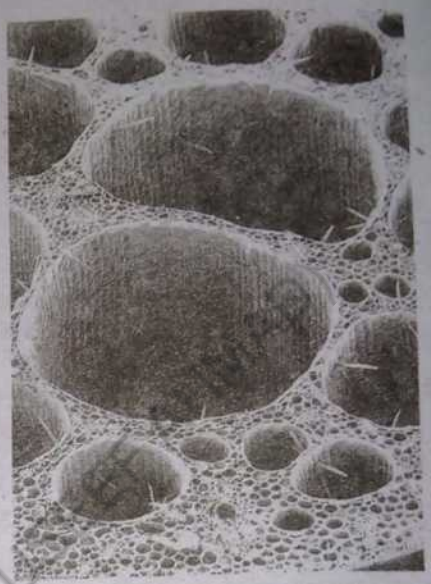
i) Hydrophytes: The plants (such as water lily), which are found in fresh-water habitat either partly or completely submerged are termed as **hydrophytes.** They do not have any difficulty in obtaining water. The stems and leaves of hydrophytes generally lack cuticle. Their stomata are restricted on the upper surfaces of leaves in partially submerged Hydrophytes.

Ii) Halophytes: The plants growing in salt marshes close to sea are termed as halophytes. Some of the examples of halophytes are glasswort, cord-grass, etc. They have to absorb water from such a soil, which has higher salt concentration and therefore lower water potential (higher osmotic pressure). Halophytes cope with this situation, by actively absorbing salts into their roots. As a consequence, the cells of the roots develop lower water potential which brings in water by osmosis. The

excess salt can be stored in cells or excreted out from salt glands on the leaves. The salt thus secreted by some species help them to trap water vapours from the air, which is being absorbed in liquid form by leaf cells. Therefore, this is another way for obtaining additional water from the air.



Stout rhizome rooted in the mud of the pond



Scanning electron micrograph showing the large air spaces found in the stem and petioles of many water plants

Fig: 1.2(a) The hydrophyte water lily

Glasswort (salicoma spp) is a succulent plant containing water storage cells

Cordgrass (Spartina angelica) established on the edge of a salt marsh channel

Fig: 1.2(b) Typical halophytes

iii) Mesophytes: These are most of the land plants of temperate zones, which grow in well watered soil. They can easily compensate the water lost by transpiration through absorbing water from the soil, To prevent excessive transpiration, they have

Mesophytes growing in high rainfall and humid condition face the problem of losing excess water as there is low rate of transpiration. Such plants may lose surplus water through special pores called hydathodes, by a process called guttation. In this process, water is lost in liquid rather than vapour form.

developed a water proof external covering called cuticle.

iv) **Xerophytes:** Plants living in dry places such as deserts, steep hills, etc have to face scarcity of water. They are termed as **xerophytes**. Under such conditions, water potential of soil and air are very low. So the xerophytes have developed following adaptations to conserve water and to survive during drought conditions.

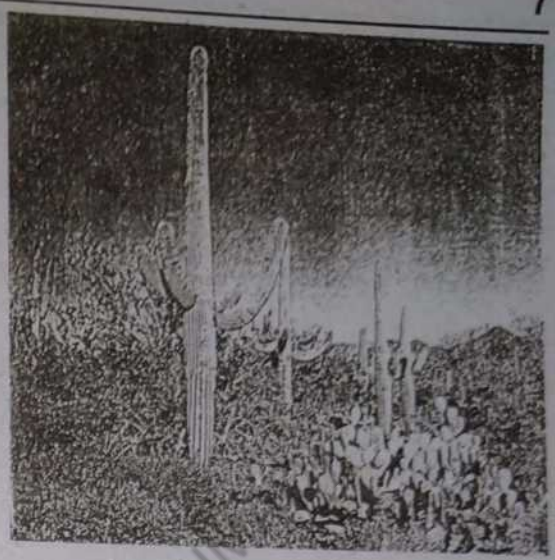


Fig 1.3
Two desert succulents

I - Seed/ Spores as adaptations in life cycle during drought condition:

Land plants produce seeds or spores during their life cycle. The protoplasms of these structures are quite concentrated and usually protected externally by hard coats and thus these structures remain viable for a considerable period of time.

II - Adaptation for balance between transpiration and water uptake:

a) Development of very deep vertical roots for the better absorption of water from the soil as seen in *Acacia*, *Banyan*, etc.

b) Other plants such as Cacti have superficial, horizontal roots which can absorb water before it evaporates from the soil.

c) Reduction in number of stomata, Sunken type of stomata, development of hairy epidermis, folding of leaves, reduction in size of lamina and modification into spines are some of the adaptations for reducing the rate of transpiration.

d) Some plants store water in large parenchymatous cells present in stem or leaves. Such plants are termed as **succulents**. As a result, the stem or leaves become juicy.

1.2.4 Osmoregulation in terrestrial and aquatic animals:

Mechanism of osmoregulation is also very important for all groups of animals whether inhabiting land or water. Unlike plant cells, animal cells when placed in hypotonic solution burst due to the continuous absorption of water. On the contrary, they would shrink and die if constantly placed in hypertonic solution. However, normally uptake and loss of water are in balance for proper survival of cell.

1. Osmoregulation in terrestrial animals:

Terrestrial animals are more likely to lose water by evaporation through their permeable surfaces exposed to atmosphere. Among various animal groups, only Arthropods and Vertebrates became the most successful land dwellers. They have developed number of strategies to maintain osmoregulation of their body fluid.

a) Water proof external coverings: To prevent water loss through external surfaces, vertebrate like reptiles, birds and mammals have water proof keratinized epidermis. Similarly the insects have developed an external water-proof layer called cuticle.

b) Storing and excretion of solid wastes: Reptiles, birds and insects excrete uric acid as nitrogenous waste, which is insoluble in water. It is stored temporarily in cloaca where water is reabsorbed from it before its removal from the body in semi-fluid form.

c) Use of metabolic water: Some mammals like camel, kangaroo-rat etc. make use of water produced during the break down of body fats.

d) Storing the wastes: Mammals do retain some urea in their kidneys where it helps in reabsorption of water.

2. Osmoregulation in aquatic (Fresh-water) animals:

a) Osmoregulation by contractile vacuole: Fresh-water protoctists like *Amoeba*, *Paramecium*, etc. bear one or more membrane bound, tiny sac called contractile vacuole. Since such fresh-water protoctists have higher osmotic pressure than their surrounding water so the water constantly comes in by osmosis. If it is not regulated, the organism would burst. Therefore, the excess water is stored in contractile vacuole. After, it is completely filled, water is discharged out of the cell through a pore into the surrounding water.

b) Osmoregulation by producing dilute urine: Fresh water animals like fishes have a hypertonic body fluids than the surrounding water. Thus they remove excess water by passing large quantities of very dilute urine. During the excretion process, they lose some essential ions as well. However this is overcome by actively absorbing selected ions from outside, through gills.

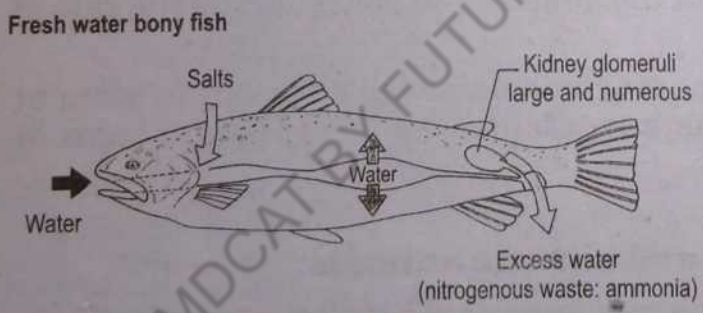


Fig 1.4(a) Summary of osmoregulation in a freshwater bony fish such as a trout

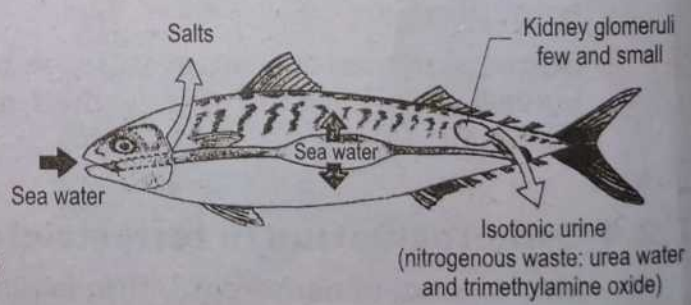


Fig 1.4(b) Summary of osmoregulation in a marine bony fish such as a mackerel

3. Osmoregulation in aquatic (marine animals):

Marine bony fishes have hypotonic internal environment so they are liable to lose water. Thus in order to conserve water, they constantly drink water. The salts taken in alongwith water are actively excreted by special excretory cells in the gills. Moreover, the filtration rate in their kidneys is very low so small quantity of concentrated urine is excreted.

Marine invertebrates as well as hag-fishes have isotonic body fluids so they do not have osmoregulatory mechanism. Such animals are termed as osmoconformers.

Unlike marine bony fishes, sharks and rays maintain relatively slightly hypertonic osmotic pressure of body fluids than their surroundings by storing high concentration of urea in their bodies. Thus they do not have problem of water loss. Excess salts are removed by special glands in their rectum.

1.3 EXCRETION

This aspect of homeostasis refers to the process of removal of metabolic wastes; excess substances such as salts, water, and toxic substances such as drugs from the body. However, in a restricted sense, it is the process of removal of nitrogenous metabolic wastes from the body of organism. Such wastes are formed as a consequence of proteins and nucleic acid metabolisms.

1.3.1 Excretion in Plants:

For a number of reasons, excretion in plants does not pose serious problems. First, the rate of catabolic processes is much less than the animals of same weight or mass. Thus metabolic wastes accumulate more slowly. Moreover, waste products of catabolism are used by green plants in their anabolic processes. Green plants do not excrete nitrogenous wastes, on the contrary they recycle breakdown products of nitrogen metabolism. Secondly, the metabolism of plants is mostly carbohydrate based and its end products CO_2 and water are far less harmful than the nitrogenous wastes produced by protein metabolism in animals. As such plants do not possess any organ exclusively meant for excretion as in the case of animals.

However, certain substances, which accumulate to levels in excess of plants needs, such as water, carbondioxide, oxygen and certain ions, are to be eliminated.

Plants get rid of surplus water by losing it in vapour form which diffuse out through stomata. This process is known as **transpiration**. Some land plants exude water from points called **hydathodes** found at the margins and tip of leaves. This loss of water in liquid form is known as **guttation**. It is common in plants growing in tropical rain forests where rate of absorption is higher due to high rain fall and rate of transpiration is much low due to high humidity.

Green plants, in light, release oxygen because rate of photosynthesis is much higher than the rate of respiration. At dark, plants release CO_2 because respiration is going on whereas photosynthesis is not.

Ions present in excessive concentration combine with organic compounds and are deposited in dead cells such as heartwood and bark or in the cells which are at the point of their death.

1.3.2 Excretion in Animals:

In the proceeding discussion we shall restrict the process of excretion as removal of nitrogenous metabolic wastes. In different groups of animals, different nitrogenous substances such as ammonia, urea, uric acid, creatinine or

trimethylamine oxide, hypoxanthine, etc are produced as a consequence of proteins and nucleic acid metabolism. However, we will discuss the first three due to their higher toxicity.

1. Excretory products and their corelation with habitat of animals:

Ammonia (NH_3): It is a small gaseous molecule and is highly soluble in water. It can diffuse very rapidly across the plasma membrane even when dissolved in water. This nitrogenous waste is highly toxic if remains in the organism. Its toxicity is reduced when diluted with large quantities of water. Excreting ammonia by an animal is advantageous due to the reason that its diffusion is rapid across the plasma membrane or body surface and also due to the fact that it does not require energy. However, its removal requires a lot of water for its dilution. Therefore, it is typically associated with aquatic animals particularly fresh water habitat.

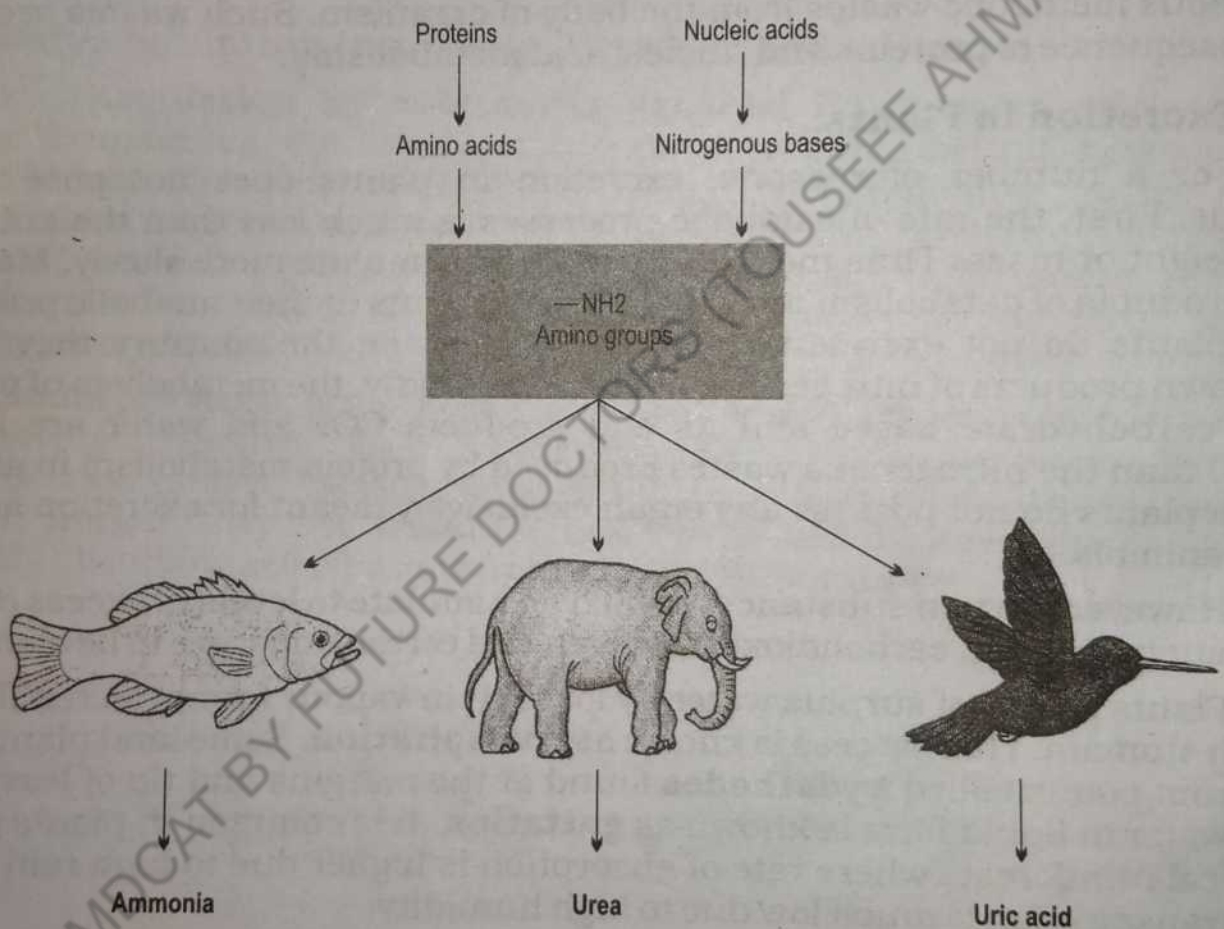


Fig 1.5 Nitrogenous wastes

In soft bodied invertebrates, the entire body surface is involved in the removal of ammonia from the body. In fish, most of the ammonia is excreted through gills as ammonium ions with kidneys playing a minor role in the excretion of nitrogenous wastes.

Urea ($CO(NH_2)_2$): Urea is relatively less soluble in water and about 100,000 times less toxic than ammonia. Therefore, it can be tolerated by an animal in much more concentrated form. Terrestrial animals such as mammals, who cannot afford to lose a lot of water during the excretion of nitrogenous wastes switched over from ammonia to urea.

However, conversion of ammonia to urea requires ATP. Urea is produced in the liver by a metabolic cycle that combines NH_3 to CO_2. In addition to mammals, most amphibians, sharks and some bony fishes also excrete urea.

Uric acid ($C_5 O_3 N_4 H_4$): It is relatively larger molecule with extremely low solubility in water. It is produced as colloidal substance. Thus further absorption of water results in its crystallization of urates. Formation of uric acid requires ATP. The suspension of uric acid is discharged either in the form of thick paste or as solid pellets.

Uric acid is excreted by terrestrial animals such as birds, many reptiles, insects, gastropods, etc who need to minimize loss of water and have eggs enclosed in shells.

2. Excretion in *Hydra*, *Planaria*, Earth worm and Cockroach:

Excretion in *Hydra*:

In *Hydra* nitrogenous waste is in the form of ammonia. Almost all the cells of *Hydra* are in direct contact with water, so ammonia is removed by simple diffusion from the external surface as well as internal surface into the external and internal water of gastrovascular cavity.

Excretion in *Planaria*:

Free-living flatworms like *Planaria* have developed a tubular excretory system. In Planaria the excretory system (Fig:1.6) consists of two longitudinal, branching tubules or excretory canals lying on either lateral side and extending along the entire length of the animal. Each tubule opens to the external surface of the animal by many excretory pores. Internally, in the mesenchyme, each tubule gives rise numerous blind bulb-like cells called **flame cells** or **protonephridia**, which are bathed in the tissue fluids. Each flame cell is hollow inside and bears a tuft of cilia which beat in manner like flickering flame (hence called flame cell), water alongwith ammonia diffuse from the tissue fluid into the lumen of flame cells. The beating of cilia propels this solution into the excretory canal where it is to be excreted out by excretory pores. During the movement of excretory fluid, water is being reabsorbed if required by the animal, and the rest of the excretory fluid (urine) is passed out in the form of hypotonic solution. Thus it seems that flame cell functions mainly in osmoregulation and most metabolic wastes are removed from body surface or excreted in the gut where they are removed through the mouth alongwith the undigested food. However, in some parasitic flatworms, which are isotonic to the body fluids of their hosts, the flame cell perform excretion of nitrogenous wastes.

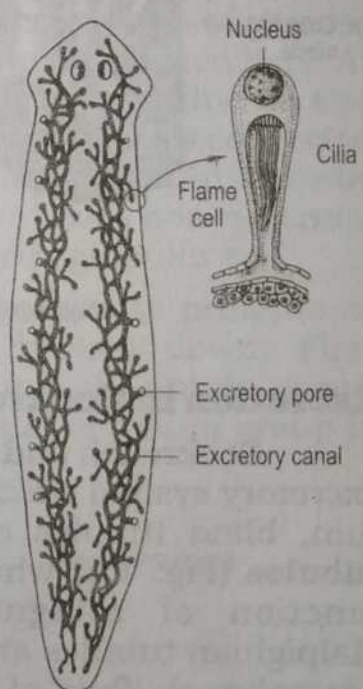


Fig 1.6 Flame-cell system of Planaria

Excretion in Earthworm:

Earthworms have combined excretory and osmoregulatory organs called **metanephridia**, which are arranged segmentally. Each metanephridium is a highly coiled tubule immersed in coelomic fluid and surrounded by a network of capillaries. It is opened at both the ends. Its internal opening called **nephrostome**, which lies in the coelom is a ciliated funnel like structure. While the external minute opening or nephridiopore opens outside in the skin. The coiled tubular part dilates finally to form a bladder before opening to outside through nephridiopore. Due to the beating of cilia of nephrostome, coelomic fluid is sucked into the excretory tubule. Some excretory substances are also secreted by cells of the tubule. Here selective re-absorption of useful substances also occurs, which are taken back by the blood into the circulation. Finally, the excretory fluid (urine) is emptied in the bladder, which excrete it outside through nephridiopore.

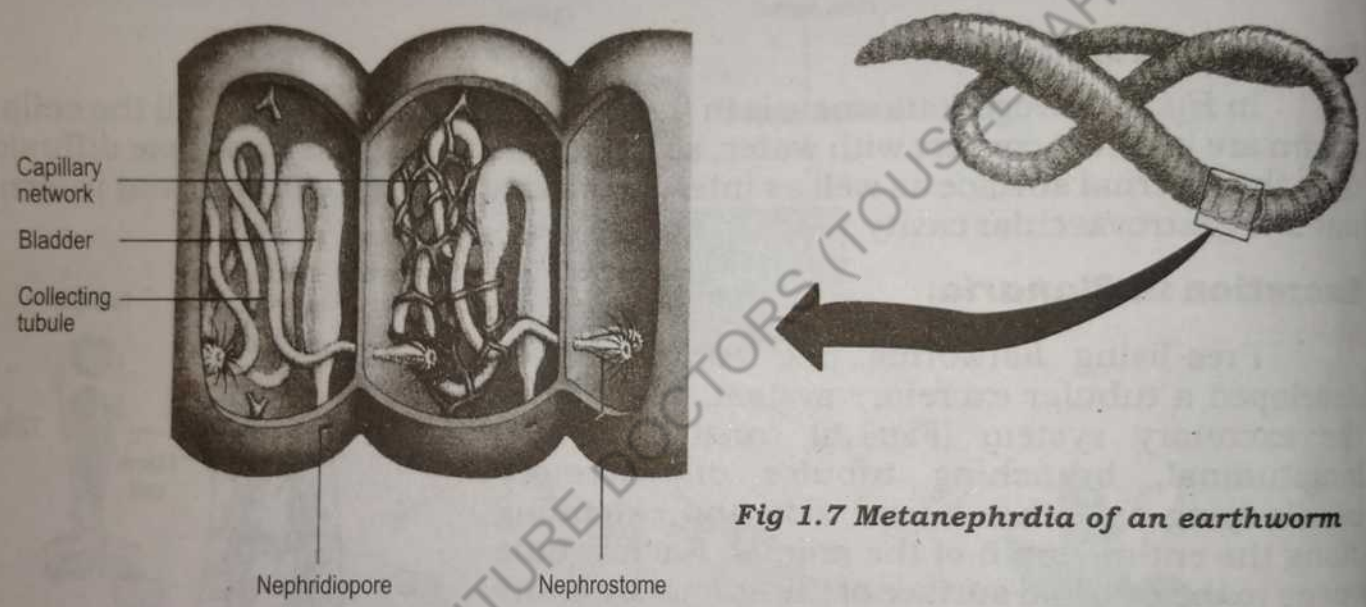


Fig 1.7 Metanephrdia of an earthworm

Excretion in Cockroach:

Cockroach and other insects have excretory system which consists of long, thin, blind tubules called **malpighian tubules** (Fig: 1.8) which arise from the junction of **midgut** and **hindgut**. Malpighian tubules are immersed in the haemolymph (fluid of body cavity). Cells of malpighian tubules absorb the excretory wastes alongwith some useful substances present in haemolymph. In the latter part of the tubule, selective reabsorption of useful substances occur and the uric acid is discharged into the rectum. Rectum stores uric acid for the reabsorption of salts and water so the uric acid becomes almost dry and pass out alongwith faeces.

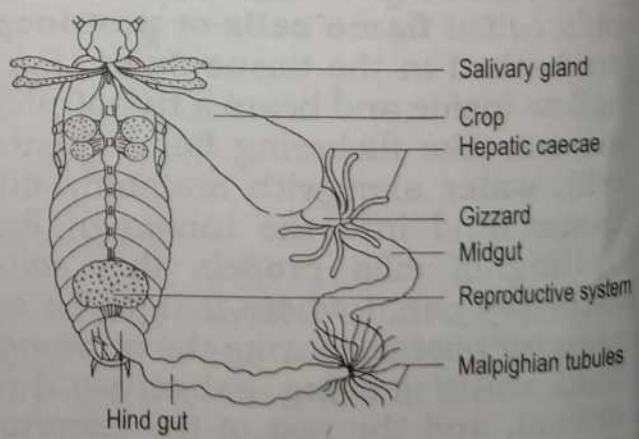


Fig 1.8 Excretory system of Cockroach

3. Excretion in man:

Keeping in mind a broader sense of excretion, i.e. removal of unwanted metabolic by-products, excess salts and excess water, we can safely conclude that excretory organs in man as well as other mammals are comprised of kidney, liver and the skin. These organs play extremely important role in maintaining homeostasis in the body.

Kidneys maintain osmoregulation and eliminate nitrogenous wastes, excess salts and excess water. **Liver** excretes nitrogenous wastes, bile pigments etc. **Skin** excretes salts and some other substances alongwith sweat during perspiration.

a) Liver—an important homeostatic organ:

Liver is a large reddish brown glandular organ located in the abdomen just below the diaphragm. It is a metabolic centre therefore it is richly supplied with blood. A sac-like gall bladder is attached with it for the storage of bile secreted by liver. Bile is poured into the duodenum by commun bile duct. Rest of its products are released into the blood through hepatic vein.

Although liver performs hundreds of functions we are restricting here to some of its main homeostatic functions.

Metabolism of carbohydrates and lipids: It maintains concentration of glucose in the blood. If glucose is in excess it is converted into glycogen and stored here. At the time of shortage of glucose in blood, glycogen is broken down into glucose and supplied to the body. If glycogen store is depleted, then amino acids may converted into glucose by the liver. It removes lipids from the blood either by oxidation or by modification and subsequently stores as fat. It can also synthesizes non-essential amino acids, as well as plasma proteins like prothrombin, fibrin, globulin etc.

Deamination and urea formation: The body cannot store excess proteins or amino acids so any excess amount of amino acid is broken down. First deamination, i.e. removal of amino group takes place (Fig: 1.9). Amino group (-NH2) is converted into ammonia while rest of the residual of amino group is

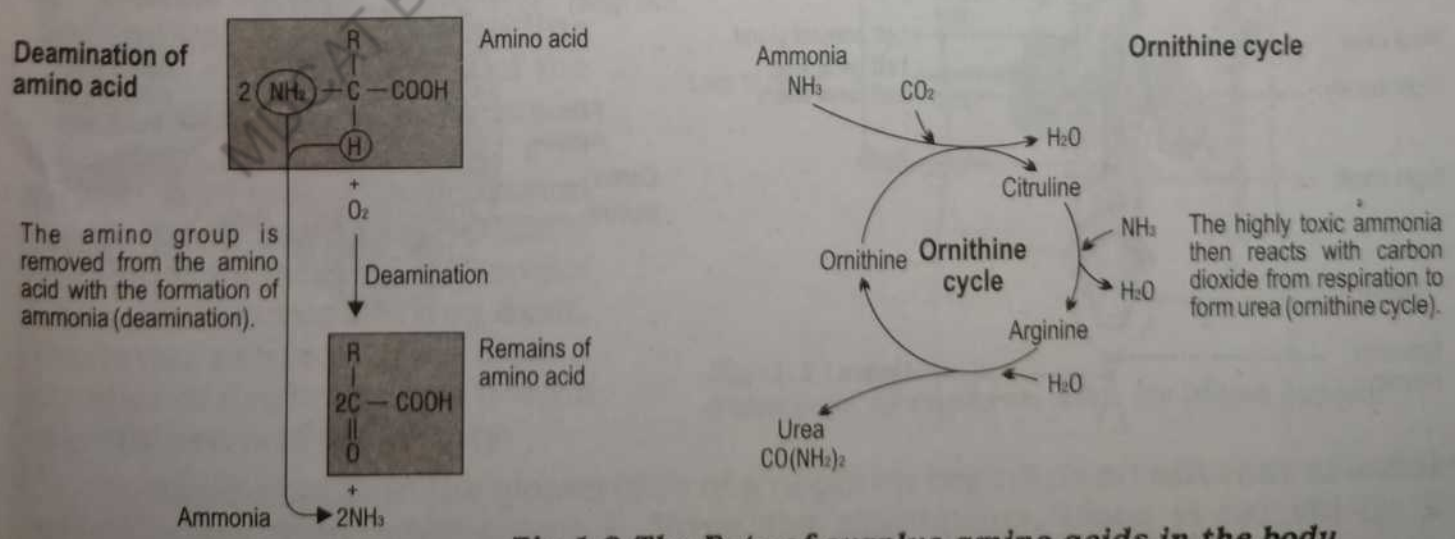


Fig 1.9 The Fate of surplus amino acids in the body

supplied to carbohydrate metabolism for respiration. Recall that ammonia is highly toxic to cells so it must not be allowed to accumulate. So ammonia is supplied to ornithine cycle (Urea cycle) in which it combines with CO_2 and converted to a less toxic substance "urea" after a series of reactions. Urea is released into the blood stream, which carries it to the kidneys for its elimination outside the body.

Production of bile: It is a yellowish green, alkline fluid containing bile pigments (such as biliverdin, bilirubin), salts (such as sodium glycocholate, sodium taurocholate), cholestrol, phospholipids and mucus. Bile pigments are the excretory products of heme part of the broken haemoglobin of worn out R.B.Cs. Its globin is broken into constituent amino acid and are recycled for new protein molecules. Bile salts are involved in the emulsification of fats in small intestine.

Detoxification: It can modify the structure of many drugs and poison to make them harmless. For instance, hydrogen peroxide, a by-product of many chemical pathways is a highly toxic substance. It is broken down to hydrogen and oxygen by an enzyme, catalase, which is present in high concentration in the cells of liver.

Formation of cholestrol: Cholestrol is chiefly synthesized here and if in excess it is removed in bile. Its excess amount in gall bladder can precipitate to form gall stone which may lead to jaundice.

Thermoregulation: Due to its efficient blood supply, large size and high metabolic rate, liver plays important role in maintaining body temperature.

Storage of vitamins: Liver stores a number of vitamins such as A, B, D.

b) Unrinary system of man:

Urinary system of man (Fig: 1.10) consists of a pair of bean-shaped organs called kidneys, a pair of ducts called ureters which arise from each kidney; a muscular sac-like organ the urinary bladder and a tube called urethra which arises from bladder and empties urine outside the body. The bladder end of urethra has a sphincter valve, which controls release of urine from the bladder.

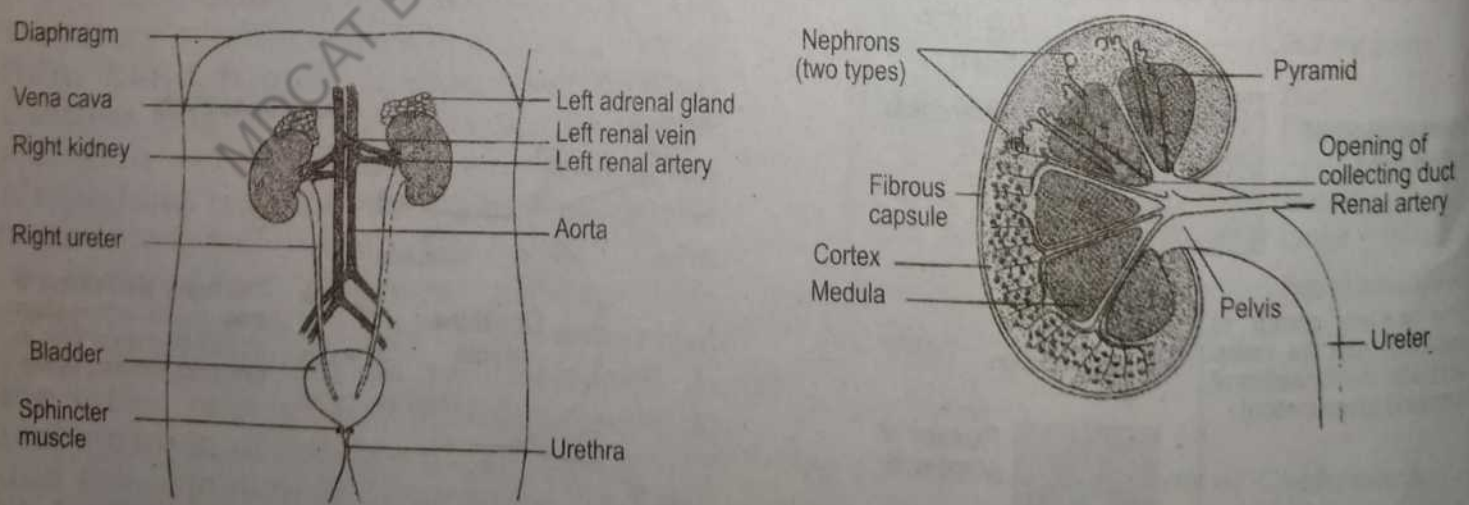


Fig 1.10 The position and structure of the human kidney

The Kidney:

Each kidney is a bean shaped organ, which is about 10 cm long. They lie in the abdominal cavity being attached with the dorsal body wall on either side of vertebral column. Each kidney is enclosed by a thin, membranous covering called **peritonium** located on the top of each kidney is adrenal gland. The kidneys receive blood through paired renal arteries, which directly arise from the dorsal aorta. The blood is drained out from each kidney by a renal vein. Both renal arteries enter and renal veins leave kidney at the site called **hilus**.

A longitudinal section of kidney shows that it consists of two distinct regions; an outer darker region, the cortex and an innner lighter region, the **medulla**. The medulla consists of many cone shaped structures called **pyramids**. Urine is dropped continuously from the tips of pyramids into funnel shaped spaces called **pelvis** of the ureter.

Nephron: Each kidney is composed of about a million microscopic tubules or nephrons. It is regarded as structural and functional unit of kidney, which performs osmoregulation as well as excretion.

Each nephron begins with a spherical structure called **malpighian** body. It lies in the cortex of kidney. Malpighian body is composed of cup-like **Bowman's capsule**. Inside this cup lies a dense network of capillaries known as **glomerulus**.

The Bowman's capsule gives out a coiled tubule known as **proximal convoluted tubule**. It lies in the cortex region. A network of capillaries is also attached with proximal convoluted tubule. The proximal convoluted tubule narrows and descends down into the medulla, makes a U-turn and comes back in the cortex. This narrow U-shape part of tubule is known as **loop of Henle**. Thus it has a descending and an ascending limb. The ascending limb of the loop of Henle becomes larger in diameter in the cortex and forms a coil called **distal convoluted tubule**. The distal convoluted tubule finally opens into a common **collecting duct**. The latter receives urine from a number of nephrons and drains into the pelvis of the kidney.

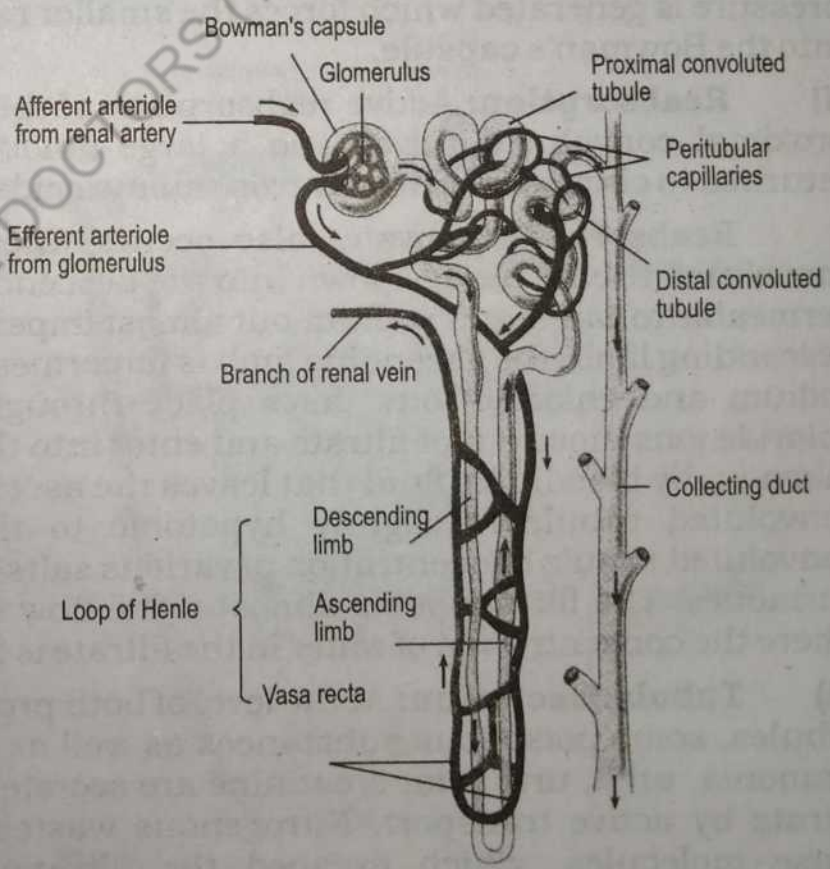


Fig 1.11
Structure of nephron with its blood supply

Blood supply to the glomerulus of a nephron begins as an **afferent arteriole**, which arises from renal arteriole. From the glomerulus, blood is carried by the

efferent arteriole into two capillary networks. One of the network called **peritubular capillaries** is associated with proximal and distal convulated tubules while the other one called **vasa recta** runs straight parallel besides the limbs of the loop of Henle.

Regulatory functions of kidney:

The kidney performs regulatory functions by different processes, viz, filtration, reabsorption, tubular secretions and counter current exchange. These processes are carried on at the level of each nephron.

> It has been calculated that about 1100 to 2000 liters of blood flows through the kidney each day. The nephrons and collecting ducts processes about 180 liters of filtrate, but the kidneys excrete only about 1-2 liters of urine. The rest of the filtrate is reabsorbed into the blood.

i) Ultra filtration: In the first stage non-selective, ultra filtration (filtration at molecular level) of blood occurs while passing through the glomerulus of the malpighian body. Two factors are responsible for this ultrafiltration. Both the capillary walls of glomerulus and the walls of Bowman's capsule are sieve-like in nature, which permit all the molecules except plasma proteins and blood cells to pass through them. Blood pressure in glomerulus is high because the diameter of efferent arteriole is much less than that of afferent arteriole. Thus a hydrostatic pressure is generated which forces the smaller molecules of blood from glomerulus into the Bowman's capsule.

ii) Reabsorption: Active reabsorption of the glomerular filtrate occurs in the proximal convoluted tubule, so a large amount of filtrate is reabsorbed and returned to circulation. Here glucose amino acids, water, salts are reabsorbed.

Reabsorption of water also occurs when the filtrate from the proximal convoluted tubule passes down into the descending limb of the loop of Henle. It is permeable to water and sodium but almost impermeable to any solutes. Unlike the descending limb, the ascending limb is impermeable to water. Here reabsorption of sodium and chloride ions takes place through active transport. Sodium and chloride ions move out of filtrate and enter into the interstitial fluid where they are taken up by blood. The fluid that leaves the ascending limb and collected by distal convoluted tubule is slightly hypotonic to the blood plasma. In the distal convoluted tubule concentration of various salts is adjusted under the influence of hormones. The filtrate being almost urine now is passed into the collecting duct where the concentration of water in the filtrate is finally adjusted.

iii) Tubular secretion: At the level of both proximal as well as distal convoluted tubules, some poisonous substances as well as nitrogenous substances such as ammonia, urea, uric acid, creatinine are secreted from the blood directly into the filtrate by active transport. Nitrogenous wastes added in this way are actually those molecules, which escaped the filtration in glomeruli. Hydrogen and Ammonium ions secretion from the interstitial fluid into the distal convoluted tubule plays important role in the maintenance of acid-base balance in the blood.

iv) Counter-current exchange: There are two counter-current systems operating in the medulla which are involved in the exchange of solutes and water.

One of the counter-current is termed as counter-current multiplier in the loop of Henle. This counter-current multiplier is involved in developing concentration of ions across the medulla. While passage of isotonic filtrate through the descending limb, the reabsorption of water turns the filtrate gradually hypertonic to the tissue fluid. Subsequently, in the ascending limb, the sodium and chloride ions are actively removed from the filtrate, thus reducing the hypertonicity and turning it into hypotonic. The sodium and chloride ions removed from the ascending limb slowly diffuse back in the descending limb. This maintains highest concentration of solutes (Na, urea) in the inner medulla. Due to the hypertonic environment almost 90% of water of the filtrate is reabsorbed. As a consequence urine passes outside the body is hypertonic to body fluids.

The other counter current system is composed of vasa recta, the blood vessels that run parallel to the loop of Henle, only about 1% of the blood that flows through the kidney passes through the vasa recta at a very slower speed. The blood supply to vasa recta provides sufficient nourishment and oxygen to the cells of medulla and also takes away the water absorbed from the filtrate, without affecting the concentration gradient of medulla.

Adaptations of Kidney and effect of hormones on its working:

Structure of kidneys is adapted to the natural habitat of animals. For example, mammals that must conserve water do so by passing more concentrated urine. The degree of concentration of urine is determined by the length of the loop of Henle. Generally longer length of the loop of Henle causes higher concentration of salts in the medulla which is ultimately related to higher rate of exosmosis of water from the collecting duct thereby more concentrating the urine.

This is supported by the presence of two types of nephrons; i.e. cortical nephron and juxta-medullary nephrons in the kidney. Cortical nephron has short loop of Henle with a slight extension into the medulla. On the contrary, juxtamedullary nephron has longer loop of Henle extending deep into the medulla. Thus greater the demand of conserving water, the greater would be the number of juxta-medullary nephrons in the kidney.

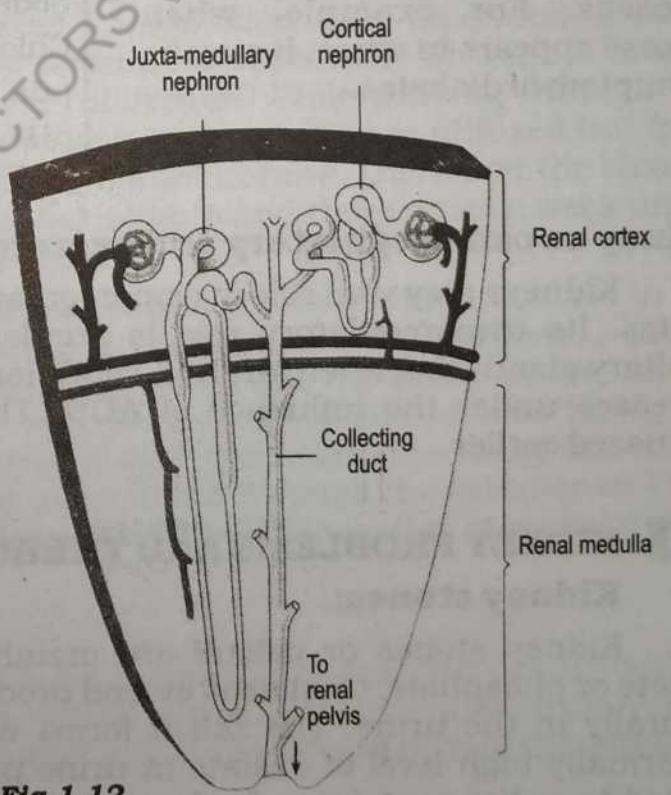


Fig 1.12
Cortical and juxta-medullary nephrons

Effects of hormones on the working of kidney:

The permeability of the walls of the collecting ducts to water is regulated by **antidiuretic hormone** (ADH) or **vasopressin**. It is secreted by posterior pituitary

gland in response to increased osmotic pressure of the blood (i.e. dehydrating condition). Due to the presence of ADH, the reabsorption of water in the collecting duct is increased.

The concentration of sodium ions in the body fluids is controlled by another hormone called **aldosterone** secreted by adrenal cortex. It increases the reabsorption of sodium ions in the nephron. Similarly the concentration of calcium ions in the blood is controlled by **parathormone** secreted by parathyroid gland. It increases the reabsorption of calcium ions in nephron.

Composition of urine and variation in the composition and its significance:

It has been estimated that the urine contains about 95% water and 5% solids. The average values of various substances per 100 cm^3 are summarized in the table.

The analysis of composition of urine sample is an important medical procedure in diagnosis of various metabolic disorders, infections, pregnancy and kidney diseases. For example, when glucose appears in urine, it may be a symptom of diabetes.

Components	Composition (concentrations/100cm^3)
Water	95.00
Proteins	00.00
Glucose	00.00
Urea	02.00
Creatinine	0.3-0.70
Ammonia	0.3-0.70
Uric acid	0.30
Sodium	0.30
Chlorides	0.60
(Ca, Mg, K, PO, SO)	0.47
pH	5.00

Kidney as osmoregulatory and excretory organ:

Kidneys play vital role in osmoregulation as well as excretion of nitrogenous wastes. Its osmoregulatory role is regulated by ADH released from posterior pituitary gland under dehydration condition. The reabsorption of water in kidney increases under the influence of ADH. The excretory role of kidney has been discussed earlier.

1.4 KIDNEY PROBLEMS AND THEIR REMEDIES

1. Kidney stones:

Kidney stones or calculi are mainly (about 70%) composed of calcium oxalate or phosphate. Oxalate is an end product of body metabolism and is present naturally in the urine. The salt it forms with calcium has a low solubility. An abnormally high level of oxalate in urine promotes stone formation and may be related to a diet containing food or drinks with a high content of oxalic acid, for instance tomato, spinach, leafy vegetables etc.

About 20% of calculi are termed as infective stones. Such calculi consist of combination of calcium, magnesium and ammonium phosphate. Some stones (about 5%) are formed by uric acid.

Lithotripsy:

Lithotripsy is a recent method for removing kidney and ureteral stones. In this procedure shock waves or ultrasonic waves are used to break up calculi for removal. Ultrasonic lithotripsy involves the use of an ultrasonic probe through a telescopic tube to help break up the stones. Shock wave lithotripsy is more advance method in which shock waves are being focused on stones from outside the body. After being broken, the smaller fragments are passed in urine.

2. Renal failure:

It is a condition in which there is a reduction in the ability of the kidneys to filter waste products from the blood and excrete them in urine, for osmoregulation and to regulate the blood pressure. As a consequence the nitrogenous wastes start accumulating in the blood which leads to the symptoms such as nausea, vomiting, loss of appetite, weakness, breathlessness etc. In severe cases, it leads to coma and death. Associated complications may include pneumonia, bleeding in the stomach, high blood pressure etc.

Dialysis:

It is a technique used to remove waste products from the blood and excess fluids from the body as a treatment for renal failure. There are two methods of a dialysis i.e. **haemodialysis** and **peritoneal dialysis**.

Haemodialysis makes use of **kidney machine** or an artificial kidney containing a fluid of carefully adjusted composition (the dialysate). During haemodialysis, the blood from the body is pumped repeatedly through a tube of partially permeable membrane bathed in dialysate. While passing through the dialysis machine, the nitrogenous wastes and excess salts are diffused out from the blood into the dialysate through the dialysis membrane. Thereafter the blood is returned to the circulation. It goes on for 6-10 hours and three times a week under strict regulation of diet and proper fluid intake.

Peritoneal dialysis requires an abdominal incision which is done in the hospital. Through the incision a catheter is inserted into the peritoneal cavity. Dialysate from a bag attached to the catheter passes into the cavity where it is left for several hours. As a consequence, wastes from the blood vessels lining the peritoneal cavity seep through the peritoneal membrane into the cavity and mixes with dialysate. The fluid is then allowed to drain out through the catheter and into the empty dialysate bag. The process takes about an hour and is repeated during the day or overnight.

Kidney transplant:

In young patients having kidney failure, transplantation of a healthy kidney that will be accepted by the body and function normally is preferable to dialysis as long term solution. It is a surgical procedure and successful in 80% of the cases.

1.5 THERMOREGULATION

It is the maintenance of body temperature within a range that enables the body to function effeciently. The normal temperature range for active life is 10 °C to 35°C for most of the organisms. The temperature influences directly upon the membrane properties as well as metabolism of cells.

1.5.1 Adaptations of plants to low and high temperature:

Low temperature: Low temperature affects the fluid nature of plasma membrane of plant cell. It is ultimately related to affect the transport of solutes across the membrane. Under such conditions the plants cells increase the proportion of unsaturated fatty acids which prevent crystal formation. The low temperature at the level of freezing point causes ice crystal formation in cell. This is avoided by the plants inhabiting cold regions by developing freezing tolerance in which the composition of solutes of cell is altered in a way that ice crystals are formed in the cell wall rather than the **cytosol**. The cytosol is super cooled below the freezing point without the formation of ice.

High temperature: High temperature is more harmful than low temperature since enzymes are denatured, which is disastrous for metabolism. The principal way to cool down the plant in this situation is transpiration, i.e. evaporation of water mainly through stomata. At 40°C or above, most of the plant cells synthesize heat shock proteins that protect enzymes and other proteins from denaturing due to higher temperature. In addition to these mechanisms plants have some other ways of avoiding overheating such as shiny cuticle, a small leaf surface area, wilting, etc.

1.5.2 Thermoregulation in animals:

Sources of body heat gain and heat loss:

Organisms obtain heat energy from two basic sources i.e. externally and internally. **Externally**, heat is obtained either directly from solar radiation or indirectly by radiation, convection and conduction from the environment which in turn is warmed by solar radiation. **Internally**, heat is obtained as a by-product of metabolism and muscular contractions.

Organisms lose heat by radiation, conduction and convection from their surfaces and through evaporation of water.

1.5.3 Ectothermic and Endothermic animals:

Animals can be divided into two categories on the basis of their thermal characteristics; **Poikilotherms** (cold blooded) and **Homoiotherms** (warm blooded).

Poikilotherm (Gr. having variable temperature) are those animals whose body temperature changes in accordance with the fluctuations of the environmental temperature. All invertebrates, fishes, amphibia and most reptiles fall into this category. Homoiotherms (Gr. having the same temperature) are those animals who have constant body temperature which is independent of the environment.

However, both of these terms have been discarded because number of poikilotherms maintain a constant body temperature. In contrast the body temperature of homoiotherm is not always, constant. Under the circumstances the terms poikilotherms and homoiotherms have been replaced by **ectotherm** and **endotherms**, respectively.

Ectotherms are those animals who absorb heat energy from their environment, for instance lizards basking in the sun. They have behavioural means of thermorgulation. Endotherms are those that generate their own heat energy. They have physiological as well as behavioural means of thermoregulation.

Another category is **heterotherms** that generate heat of varying degrees so their body temperature is kept in a wider range. Bats, humming birds, etc. fall into this group.

1.5.4 Means of thermoregulation in animals:

As discussed earlier, animals regulate their temperature either by their behaviour or by behaviour as well as by their physiology. Thus, thermoregulation is of two types behavioural and physiological.

i) **Behavioural regulation:** This regulation involves some behavioural means exhibited by an animal. For instance, many animals can increase or decrease heat loss by changing their location. They will bask in the sun or on warm rock in winter; find wet, cool area or burrow in summer; or migrate to a more comfortable climate. All ectotherms employ behavioural means of thermoregulation.

ii) **Physiological regulation:** It involves the regulation of body temperature by some physiological means. It is exhibited by slight change in the blood circulation pattern, change in the rate of metabolism, cooling by evaporative heat loss and activation of certain muscles. It is one of the characteristics of endotherms.

1.6 THERMOREGULATION IN MAMMALS (MAN)

The basal metabolism of the body generates heat in endotherms including birds and mammals, that maintain high body temperature within the range of 36-43°C (mammals 36-38°C ; birds 41-43°C). In maintaining the body temperature they have to regulate the heat loss / heat conservation also.

There are two ways to increase heat production; viz. shivering thermogenesis and nonshivering thermogenesis. Shivering thermogenesis is the heat production by means of increasing contraction of muscles through shivering. On the contrary, nonshivering thermogenesis occurs due to the action of certain hormones. In some mammals, yet there is another unique way of thermogenesis due to a specialized tissue called **brown fat**, found in the neck and between the shoulders, that is specialized for rapid heat production.

1.6.1 Mechanisms of thermoregulation in cold temperature:

1. Physiological mechanisms:

(a) Non shivering thermogenesis:

i) **Erection of hair:** Hairs are raised to an almost vertical position due to the contraction of erector pili muscles in the skin.

In furry animals, the hair in vertical position can trap a thick layer of stationary air next to the skin. Due to this heat loss from the skin is reduced.

ii) **Reduction in blood flow towards skin:** The heat is transported by the blood all round in the body. In cold temperature, the narrowing of the arteriole or **vaso- constriction** occurs so the lesser blood is supplied towards the body surface to conserve the body heat. This cooling is more marked in the limbs than in the rest of the body.

iii) **Subcutaneous fat accumulation:** In mammals, fat is stored in adipose tissue below the skin. It is a bad heat conductor so it serves as a means of conserving heat. This is particularly very important for the survival of aquatic

mammals like seals, whales, walrus, etc. However, in terrestrial mammals which remain active in cooler season, fats are primarily stored as reserve food.

(b) Shivering thermogenesis:

In cold condition, the muscle tone, initially under nervous control, tend to rise. If the cold continues shivering begins which generate heat in muscles. Under persistant cooler conditions, the basal metabolic rate is raised in short term by the secretion of hormone adrenaline and in longer term by the secretion of another hormone, thyroxine.

2. Behavioural mechanism:

Behavioural mechanisms include moving to a warmer location, huddling close together with other individuals; in humans putting on additional clothes.

1.6.2 Mechanisms of thermoregulation in hot temperature:

1. Physiological mechanisms:

The physiological mechanisms involve lowering the hairs which reduces the insulating effect. Also there is a reduction in subcutaneous fat. In case excessive hot temperature evaporative cooling occurs in most of the mammals by means of secreting sweat from the sweat glands in the skin. To promote heat loss, vaso-dilation of arterioles of skin occurs so more blood flows towards the body surface. Some mammals that do not have sweat glands in skin or scanty glands in skin, perform panting. It is an efficient method of losing heat from the mouth, tongue and respiratory passage. Moreover, the metabolic rate of the body is decreased so less heat is generated by the body.

2. Behavioural mechanisms:

Behavioural means like moving to a cooler location, use of thin clothes, etc are also employed.

1.6.3 Role of brain in temperature regulation:

Hypothalamus is the part of brain, which has thermoregulatory centre. It is commonly called as **thermostat of the body** switching on and off heat loss or heat conservation mechanisms. The hypothalamus receives impulses from thermoreceptors present in skin and the deep body tissues and it also senses the temperature of blood flowing through the brain. The hypothalamus is set at a particular temperature called **set point**. Any change in the body temperature below or above the set point is detected by the hypothalamus and instructions are sent to appropriate organs to bring the body temperature back to normal. This is a complex homeostatic system, which is facilitated by feedback mechanism. In case of hot temperature, the hypothalamus shuts down the heat saving mechanisms and facilitates evaporative cooling, panting and vaso-dilations. On the contrary, in colder temperature, it inhibits heat loss mechanisms and activates heat saving mechanisms with facilitating heat-generating mechanisms.

Fever: Fever or pyrexia is defined as body temperature above normal set point, i.e. 98.6°F or 37°C. It could be result of bacterial or viral infection or non-infections. The fever in case of infection is a consequence of the activity of macrophage, which release pyrogens to raise the body temperature to inhibit the growth of pathogenic microorganisms.

KEY POINTS

- Homeostasis is a set of regulatory mechanisms, which are involved in maintaining an organism's internal environment within a suitable limit.
- Osmoregulation, excretion and thermoregulation are aspects of homeostasis.
- The check and balance system of homeostasis is called feed back system.
- Maintenance of water and solute concentration of cell is called osmoregulation.
- Depending upon the availability of water to flowering plants in their natural habitat, they are divided into four categories; Hydrophytes, Halophytes, Mesophytes and Xerophytes.
- Removal of metabolic wastes, excess substances and excess water is called excretion.
- Excretion in plants does not pose any serious problems.
- Ammonia, urea, uric acid, creatinine and hypoxanthine, etc., are excretory products in different groups of animals.
- Kidneys, liver and skin are the excretory organs in vertebrates.
- Each kidney is composed of microscopic units called nephrons.
- ADH, aldosterone and parathormone influence the working of kidneys.
- Kidney is important in osmoregulation and excretion.
- Most of the renal calculi are chemically calcium oxalates or phosphates.

EXERCISE

1. Encircle the most correct choice:

i) The capacity of a living system to lose water is

a) Osmotic pressure b) Water potential

c) Osmosis d) Plasmolysis

ii) The net movement of molecules remains in equilibrium when a cell is placed in.

a) Hypotonic solution b) Hypertonic solution

c) Isotonic solution d) None of these

iii) Plants growing in salt marshes are termed as
a) Hydrophytes b) Halophytes c) Mesophytes d) Xerophytes

iv) Plant cells, when constantly placed in hypotonic solution does not burst because of the presence of
a) Vacuole b) Plastids c) Cell wall d) Glyoxysomes

v) Plants get rid of surplus water by losing it in vapour form by process called
a) Osmosis b) Guttation c) Transpiration d) Excretion

vi) Enzymes are protected at high temperature by
A) Ice crystals b) Super cooling
c) Freezing tolerance d) Heat shock proteins.

vii) It is not a way of obtaining heat by organism
a) Solar radiation b) Metabolism
c) Muscle contraction d) Sweating.

viii) It does not happen during regulation of cold temperature
a) Sweating b) Shivering
c) Vaso constriction d) Subcutaneous fat accumulation

ix) The process of removal of metabolic wastes is called
a) Homeostasis b) excretion
c) Osmoregulation d) Thermoregulation

x) The excretory organs of annelids are
a)Flame cells b) Nephridia c) kidneys d) Liver

xi) The hormone involved in the reabosorption of water from kidneys is
a) Aldosterone b) Parathormone
c) ADH d) None of these

xii) The most abundant component of urine is
a) Urea b) Water c) Ammonia d) Uric acid

xiii) Which of the following is called "thermostat" of the body?
a) Pituitary gland b) Hypothalmus
c) Kidney d)Adranl gland

xiv) Mammals lacking sweet glands promote heat loss through
a) Aestivation b) Hibernation
c) panting d) None of these

xv) Normal set point of human body temp. is
a) 37° F b) 98.6°C
c) 30° C d) 37° C

2. Write detailed answers of the following questions:

i) Discuss categorization of plants based on osmoregulation.
ii) What is excretion? How does it occur in *Hydra*, *Planaria*, Earth-worm and Cockroach?
iii) Explain urinary system of man with illustrations.
iv) Describe the regulatory functions of kidney.
v) How does thermoregulation occur in mammals?
vi) Discuss excretion in plants.
vii) Draw a neat and labeled diagram of human excretory system.
viii) Explain common kidney problems and their remedies.
ix) Discuss the homeostatic functions of liver

3. Write short answers of the following questions :

i) Why plant cell does not burst even if placed constantly in hypotonic solution?
ii) Why hydrophytes do not have cuticle on stem or leaves?
iii) Marine Protozoa do not have contractile vacuole, Why?
iv) Define various aspects of homeostasis.
v) Define positive and negative feed backs with examples.
vi) Enlist osmoregulatory adaptations in terrestrial animals.
vii) Enlist homeostatic functions of liver.
viii) Draw the chart of ornithine (urea cycle) cycle.
xi) State the names and effects of hormones on kidney.
x) Define renal failure and kidney stones.
xi) Define fead back. Differentiate between negative and positive feed back.
xii) Why excretion does not pose problem in plants?

4. Define the following terms:

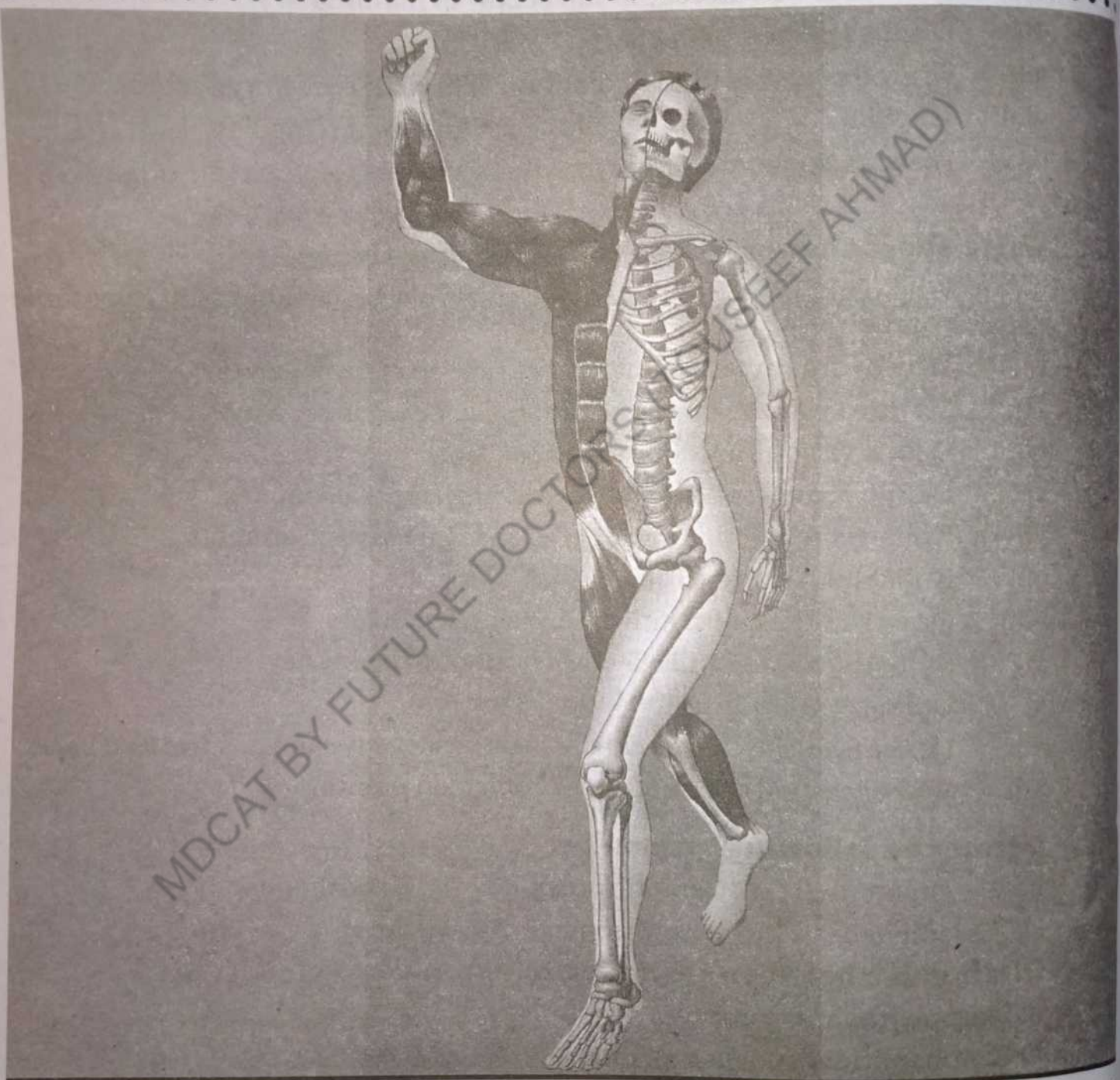
i) Water potential ii) Osmotic pressure iii) Hydathodes
iv) Halophytes v) Ectotherms vi) Fever

5. Distinguish between the following:

i) Hydrophytes and xerophytes
ii) Protonephridia and Metanephridia
iii) Ectotherms therms and Endotherms.

CHAPTER 2

SUPPORT AND MOVEMENT



Living organisms mostly respond to stimuli by exhibiting, some kind of movement or locomotion. This chapter explains the ways of support in plants and animals. Moreover, different types of movement and locomotion are also discussed.

As we know that all living organisms are made up of cells and cell having living material called protoplasm, possesses special characteristics of **irritability** due to change in its environment. In lieu of this irritability, living organism take some actions, these actions are called **movement**. In other words, we can say that movement is a response shown by a living organism towards stimuli. All living organisms having this property of movement, fulfil the need of their nutrition, protection, shelter and reproduction. Plants and animals respond to environmental stimuli in different ways. Animals are usually motile, they respond mainly by behavioral mechanisms by moving towards or away from stimuli. Plants are usually sessile which respond to environmental factors by adjusting their pattern of growth and development.

In living organisms movement can occur at cellular level, for example cytoplasmic streaming (cyclosis) and swimming of gametes, at organ level like movement of limbs and heart. Plants show cellular and organ movement. They do not locomote in search of food. They are usually capable of slow movement in response of light, gravity and water.

As the animals or plants grow in size they need support to maintain their shape and posture to stand erect for having balanced, fast and rhythmic movement. In terrestrial organisms, the need of support is much pronounced because air does not provide support like water.

Support is provided by;

- Skeletal system in animals i.e. exo, endo and hydrostatic skeleton.
- Mechanical tissues with thick cell-walls in woody parts of plant.
- Turgidity in soft parts of plants.

2.1 SUPPORT IN PLANTS

The body of higher plant can be divided into two major parts, the root and the shoot. These two parts are distinguished on the basis of their specialized morphological and physiological characteristics. They both have many tissues which are growing throughout the entire axis and keep their body erect, they require some supporting tissues and materials. These tissues and materials are present in all parts of their body e.g. root, stem branches and leaves.

Young stem has special type of anatomical arrangement, which also helps in supporting plant. The outermost layer of thin walled cells called **epidermis**. Regions beneath epidermis are generally called **cortex** and the central portion called **stele**, which mainly consist of vascular tissues and some soft tissues. This type of stem depends for its mechanical support on the following tissues:

i) Thin walled parenchyma-having turgidity.

ii) Thick walled living tissues like collenchyma and dead tissues like sclerenchyma.

iii) Stele as cylindrical core of vascular bundles.

Parenchyma a kind of simple tissue found in the epidermis, cortex and pith. These are relatively unspecialized vegetative cells. The whole body of lower

plants (Bryophytes) is made up of these tissues. They usually have thin primary walls but no secondary walls. They have a large central vacuole surrounded by a peripheral layer of cytoplasm. They are loosely packed with intercellular spaces in leaves and green herbaceous stem. They contain chloroplasts therefore photosynthesis largely occurs in these cells. They take in water by endosmosis and become extended, these extended parenchyma are turgid, exert an internal pressure called **turgor pressure**. Due to this turgor pressure these parts remain firm and rigid. If these cells lose water, they also lose turgidity, which causes wilting in herbaceous stem and leaves. Therefore, these turgid parenchyma are important for support and shape of the soft plant.

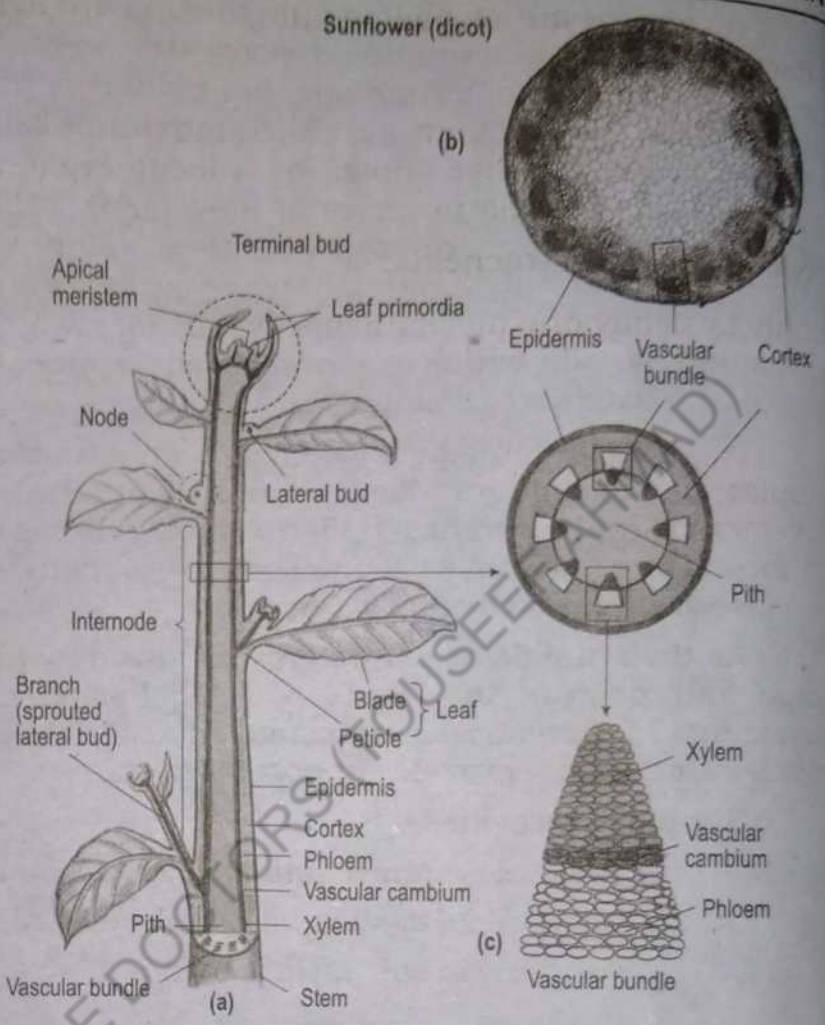


Fig: 2.1 The structure of a young dicot stem showing epidermis, cortex, vascular bundles and cambium ring. (a) Young dicot stem (b) T.S of sunflower stem (c) Vascular bundles of sunflower stem.

Collenchyma is another type of simple tissue, which is important to provide support in plants. They are also living tissues, more elongated structurally similar to parenchyma except that their walls are irregularly thickened. The thickened area is usually more prominent at edges. They function as an important supporting tissue in young plants, in the stem of non-woody older plants and in leaves.

Sclerenchyma another type of supporting tissues. They are simple fundamental dead tissues. They have uniformly thick, heavily lignified secondary walls, which give strength to the plant body. Often these walls are so thick that the lumen of the cell becomes nearly vanished. Scelerenchyma cells are two types; **fibers** and **sclereids**.

Fibers are very elongated cells with tapered ends. They are tough and strong but flexible while **sclereids** are variable, often irregular in shape. The simple unbranched sclereids are generally called **stone cells**, they are common in nut and hard parts of the seeds.

Tracheids are elongated tubular heavily lignified dead cells having large hollow cavities. They have oblique transverse walls making traeheids spindle shaped. They are found in the xylem acting as supporting tissues in addition to transport of water and dirsslved inorganic salts.

Vessels (Tracheae) are like tracheids but have no transverse walls and placed end to end forming a structure like open water pipe line. They are also found in xylem acting like tracheids.

Sclerenchyma cells provide the fibers of hams and jute, which are used for making rope. Other type of scelernchyma cells form nutshells, outer covering of Peach Pits and gritty texture of pears.

Fig: 2.2(a) The structure of xylem showing vessels, tracheids, fibre cells

Fig: 2.2(b) The structure of phloem showing sieve tube, companion cell and fibres.

2.1.1 Secondary tissues and their significance :

Secondary tissues are those which are formed by the activity of lateral meristem **vascular cambium** and **cork cambium** during secondary growth which takes place in a number of vascular plants (spermopsids). It occurs in all **gymnosperms**. Many dicot angiosperms undergo secondary growth but very few monocot plants.

1. **Vascular cambium** first appears between the primary xylem and primary phloem and called **fusiform initials** (fascicular cambium).

Then few cells of each medullar ray, lying in line with fusiform initials become meristematic to form interfascicular cambium. The two cambium combine to form a ring of meristematic tissue called vascular cambium.

Vascular cambium cuts off new cells inside as well as outside. The cells formed inside give rise to **secondary xylem**. The cells formed outside give rise to **secondary phloem**.

During secondary growth, the primary epidermis splits, dries and fall off. To protect the exposed tissues and to increase in diameter cork cambium (phellogen) arises in the cortex.

2. Cork cambium or **phellogen** appears when the layers of hypodermal cells regain the power of division to form a ring of meristematic tissue. Cork-cambium cuts off new tissues inside called **secondary cortex** or **phelloderm**. The cells cuts off outside are rectangular and arranged in radial rows. They have waxy deposition of **suberin** and become dead, they are called **cork tissue** or **phellem**. This functions as a barrier and protects the stem from physical damage and from pathogens. It also prevents from water loss.

In older trees many chemical and physical changes occur in the rings of xylem towards the center of stem. The conducting cells become blocked, parenchyma cell die while pigment, resin, tannins and gums are deposited. When these changes take place, xylem becomes non-functional for transport and emerges as strong supportive component of tree. The part of ring where these changes have occurred is known as **heart-wood** whereas the outer part of ring which contains comparatively young tissues remain functional in transport, constitute the **sap-wood**. Only youngest secondary phloem functions in sugar transport.

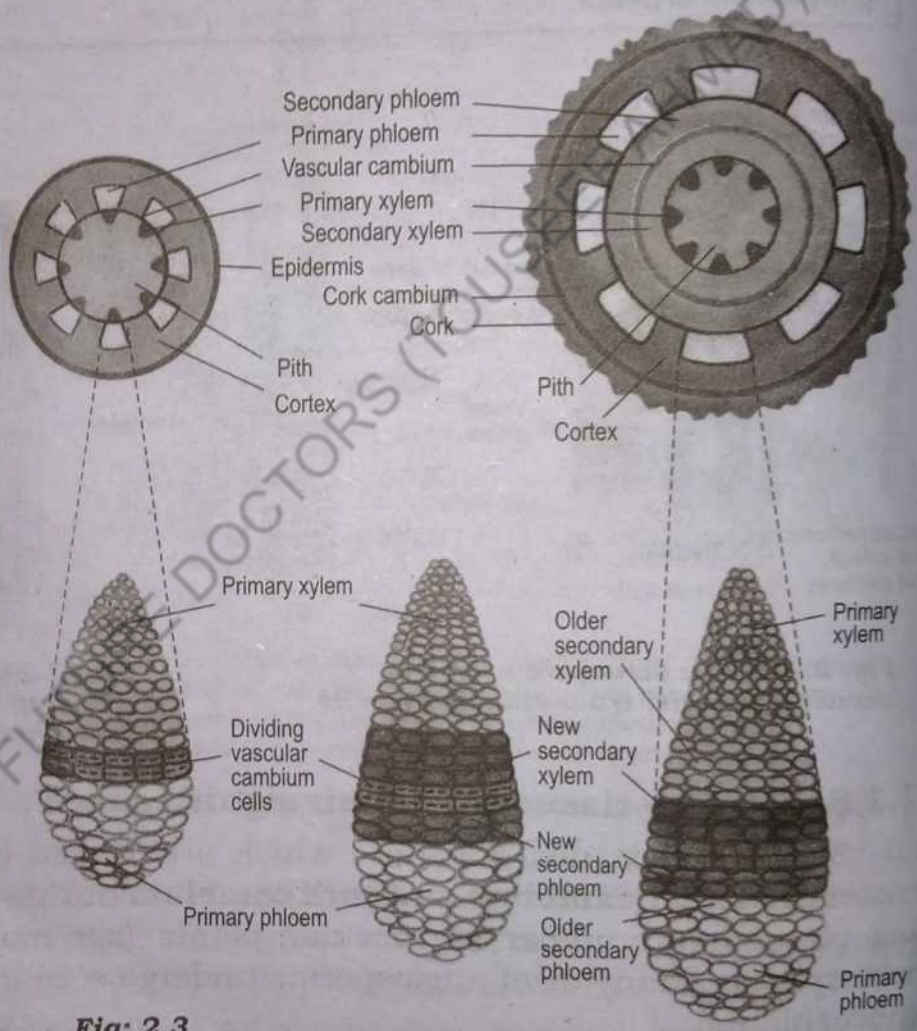


Fig: 2.3
Secondary growth in a dicot stem

In between the cork, is a spongy region in the bark, with loosely arranged cells having intercellular spaces. These masses of loose cells, through which gases and water vapour readily pass out are known as **lenticels**.

Sheets and plugs of cork come from the cork of oak trees, native of Spain, Portugal and Algeria

Significance of secondary tissues :

Secondary growth meets the need of more water, minerals and food conduction for growing plant. It also provides the firm support to it by producing new conducting and mechanical tissues. In addition to these, the cambium forms callus on or around the wound. The parenchymatous tissues are rapidly formed below the damaged surface of stem and root. Callus also develops during grafting to unite the graft with the plant.

Annual rings:

The plants of temperate region accumulate secondary xylem in the form of concentric layers every year and called annual rings.

Each annual ring consists of two zones, the inner zone of **spring wood** or **summer-wood** having larger vessels and an outer zone of **winter-wood** or **autumn-wood** having smaller vessels.

A fairly accurate estimate of age of an old tree can be made by counting annual rings. Study of the rings of large sample of very old tree can also give clue to the climate of an area. Tree ring dating have been used in archeological studies.

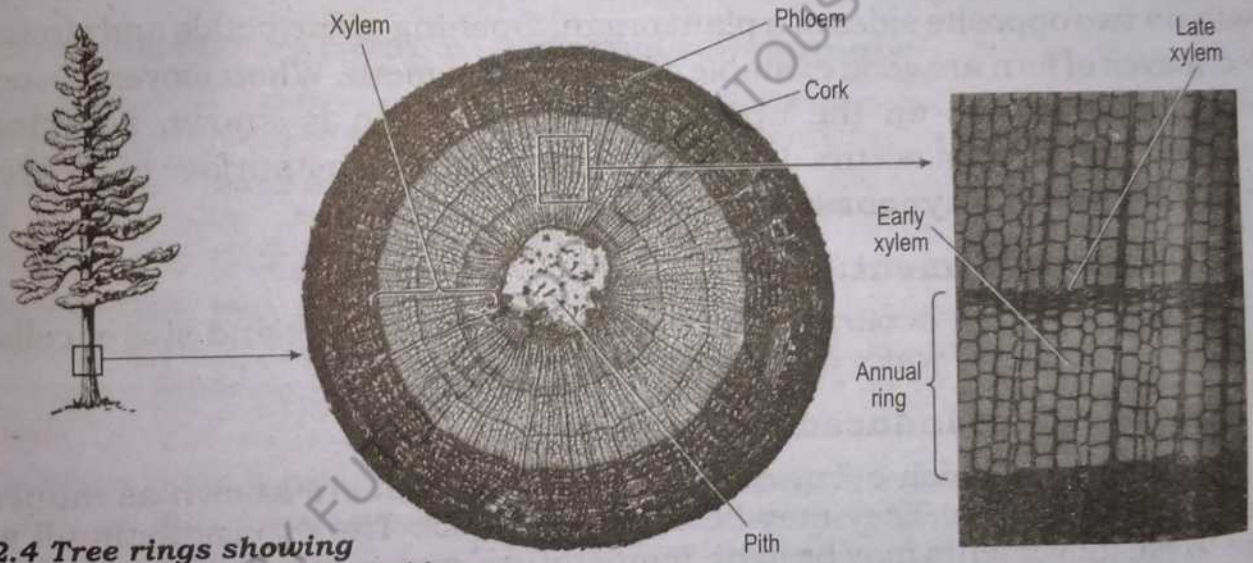


Fig: 2.4 Tree rings showing secondary wood and cork cambium

2.2 MOVEMENT IN PLANTS

Plant movements occur in response to certain stimuli, because movement is defined as any action taken by living organs to reduce its irritability produced by stimuli. Stimulus is the change in environment either external or internal which affect the living organism by developing irritation in their protoplasm. A stimulus can be diffused or directional, it may be replied with a prompt or delayed response.

2.2.1 Types of movement in plants:

On the basis of stimuli, there are two main types of movement found in plants.

1. Autonomic or spontaneous movement
2. Induced or paratonic movement

1. Autonomic or spontaneous movement:

Movement which occur due to **internal stimuli**, factors inherent inside the plant body itself are known as **autonomic** or **spontaneous** movements. Autonomic movements are of following types.

i) Growth and curvature movement:

Advantageous changes in the form and shape of plants or plant organs due to the differences in the ratio of growth of different parts are called growth and curvature movement. These movements are due to unequal growth on two side of plant organs like; stem, root, tendrils, buds, leaves etc. There are two type of growth movement.

(a) Nutation: The growth in the apex of young stem takes place in zig zag manner due to an alternate change in growth rate on opposite side of the apex, this type of movement is called nutation. A nutation movement may be **circumnutation** when apex makes rotational growth around its long axis e.g. movement of climber around the rope as found in railway creeper.

(b) Nastic movement: Movement that occurs due to differences in the rate of growth on two opposite sides of a plant organ. Opening of the petals and circinately coiled leaves of fern are good example of nastic movement. When movement occurs due to faster growth on the upper side of the organ is known as **epinastic** movement and when it occurs due to faster growth on lower surface of the growing organ, it is known as **hyponastic** movement.

(ii) Turgor movement:

Movement that occurs due to change in the turgidity and size of cells as a result of loss or gain of water called **turgor movement**.

2. Paratonic or Induced movement:

Movements which occur due to external stimuli are known as induced or paratonic movements. They may be tropic or nastic. The external stimuli which cause these movements may be light, temperature, water, chemicals, gravity etc.

i) Tropic movement: (Directional movement)

Tropism or tropic movement are growth responses that result in curvatures of whole plant organs towards or away from stimuli. It is derived from a Greek word tropos means 'turn'.

Movement caused due to external stimuli coming from one side, controlled by the direction of stimulus, respond in the form of growth of curvature in one direction called tropic movement. It is commonly found in radially symmetrical organs of plant such as root and stem. On the basis of stimuli following are the types of tropic movement found in plants.

a) Phototropism (photo = light, tropos = turn)**:** It is a curvature movement that takes place when plant is exposed to light coming only from one direction. If this

curvature movement is towards the source of light called positive phototropism and if away from the source of light called negative phototropism. Phototropic curvature is due to light effect on the distribution of **auxin** (plant growth promoting hormone).

b) Geotropism: It is the movement caused in response to gravitational stimulus. Positive geotropism is observed in the primary roots of many plants and negative geotropism in their shoot.

(c) Chemotropism (Chemo = chemical, tropos = turn)**:** Chemotropism is the movement caused due to chemical for example pollen tube grows through the style towards ovary due to **chemical stimulus**.

(d) Hydrotropism: (Hydro = water, tropos = turn): The movement of plant organs in response of water stimulus called hydrotropic movement. This also results in curvature of the organ due to unequal growth on its two sides. Roots are positively hydrotropic.

(e) Thigmotropism (Thigmos = touch, tropos = turn): Thigmotropism is the curvature movement of plant in response to touch stimulus. It can be observed in twinner and climbers. When they touch the solid object the growth on the opposite side of contact increases and the tendrils coiled around the support.

ii) Nastic movement (Non-directional movement):

The term nastic movement is used for the movement which is unrelated to direction of stimuli and direction of stimulus is not fixed. This type of movement is mostly observed in leaves and petals etc. The types of nastic movements depend on the type of stimulus, they may be photonastic, thermonastic, seismonastic, nyctinastic and haptonastic.

(a) Photonastic movement or photonasty: The nastic movement caused by light. The flowers open and close due to light intensity e.g. the flowers of oxalis and portulaca open in day and close at night while flowers of Nicotia close in day and open at night.

(b) Thermonastic movement (Therme (Gr.)= heat)**:** Nastic movement caused due to high atmospheric temperature e.g. Indian telegraph plant.

(c) Seismonastic movement (Seismos (Gr.)= to shake)**:** When the compound leaf of sensitive plant *(mimosa pudica)* is touched, it collapses and its leaflets fold together as it is undergone a shock. It results from a rapid loss of turgor by cells of the leaflets.

(d) Nyctinastic movement (Nyctos = Night/sleep)**:** Bean plants and many other members of legume family lower their leaves in the evening and raise them to a horizontal position in the morning. These movements are called sleep movement which are powerd by daily changes in the turgor pressure of the cells of the leaves.

(e) Haptonastic movement: Haptonastic movement are caused due to stimuli of touch and they can be observed in many insectivores plants in which touch causes the movement.

The distinctive feature is that, in case of thigmotropism, plant part touches the object whereas in haptonastic movement, an object (any insect) touches the plant part.

2.3 ROLE OF GROWTH SUBSTANCES IN PLANT MOVEMENT

Plant as sessile organism shows its movement mainly in the form of growth. This movement is controlled by phytohormones (auxins, cytokinin, giberellins, abscisic acid). It is found that the phototropic curvature is due to light effect on the distribution of auxin. Went (1928) found that the illuminated side of Oat Coleoptile possessed only 27% auxin where as unilluminated side possessed 57% auxin. This distribution of auxin is due to light response. The region rich in auxin grows rapidly which results in growth curvature towards the light.

Auxins also play role in geotropic responses. It is responsible for positive geotropism of roots and negative geotropism of stem. The growth rate increases with the increased accumulation of auxin and as a result a shoot will grow away showing negative geotropic property and a root because of inherent differences in response will grow towards the lower side showing positive geotropic property.

Ratio between growth inhibitors like abscisic acid and growth regulator gibberellin also play an important role in nastic movement. The epinasty is found due to auxin while gibberellin causes hyponastic movement. Role of growth substance on plant movement will be discussed in chapter 3 in plant growth regulators.

2.4 SUPPORT AND LOCOMOTION IN ANIMALS

During the course of evolution of multicellular animals many of them increased in size. If a way to support their large body had not evolved this increase in size would have not been possible. Such a support came with the development of various types of skeleton. Without the support of a skeletal system an animal could not maintain its shape and would have collapsed from its own weight to look like a mass of jelly. A skeleton cannot move without muscles, hence the skeletal and muscular systems work together to move the body around. The nervous system coordinates these two systems together.

The movement of organism also supported by Quranic Verses i.e. Allah says:

" And Allah has created every animal of water. Of them is (a kind) that goes upon its belly and (a kind) that goes upon two legs and (a kind) that goes upon four. Allah creates what He will. Lo! Allah is able to do all things."

(Sura Al-Nur 24, Ayah 45)

2.5 SKELETAL SYSTEM

A skeletal system usually consists of a single or a set of hard structures which provide the body with shape, support, protection and the power of movement.

Majority of animals lacking a skeletal system are aquatic, either sessile or slow moving.

2.5.1 Types of skeleton:

Skeletons found in majority of animals are of two general types. An **exoskeleton** completely surrounding the body like a protective encasement; and an **endoskeleton**, which forms a frame-work inside the body. In some soft bodied

animals e.g cnidarians, helminthes and annelids with no hard, outer or inner skeletal support, there is a fluid **hydrostatic skeleton** which battles with gravitational pull and provides the stiffness required for the maintenance of shape and movement of animal.

1. Hydrostatic skeleton:

This skeleton, with no hard structures, is the simplest type of skeleton found in soft bodied invertebrates. The fluid filled body of such animals work like a balloon filled with water. When one end of this balloon is squeezed the balloon becomes rigid and capable of supporting itself against the force of gravity. The fluid filled body cavity in these animals is surrounded by layers of circular and longitudinal muscles. Contraction of circular muscles put a pressure on the fluid and as a result body becomes elongated and stiff. When the longitudinal muscles contract the body becomes short and thick.

The hydrostatic skeleton helps the animals in extension and withdrawal of their bodies and tentacles. In jellyfishes and octopus, it helps in jet propulsions, the main mode of locomotion. In earthworm the alternate contraction and relaxation of circular and longitudinal muscles exert enough pressure on the body fluid to lengthen and to shorten respectively, and helps in the movement of animal in the soil. This process is assisted by anchoring, in the soil through the hard rod like structures, the setae, projecting out from the skin.

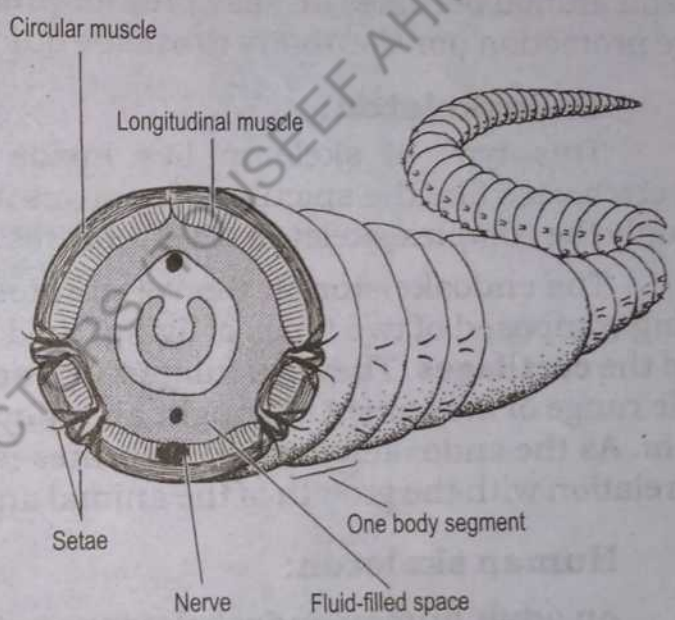


Fig: 2.5 Cross section of an earthworm

2. Exoskeleton:

An exoskeleton is a hard, **non-living** external covering that is secreted by the outer epidermal layer of the animal body itself. Exoskeletons are made up of different materials, for example molluscs have an exoskeleton (in the form of shells) made up of lime ($CaCO_3$). This type of exoskeleton provides the animal with only protection and support but not the locomotion. Another type of exoskeleton is a **cuticle** which is a hard non-living outer covering. It covers the entire outer surface of animal's body and appendages (fig.2.6). It is made up of a carbohydrate protein complex called **chitin**. This is the most complex type of exoskeleton and is found in **arthropods**. Here the

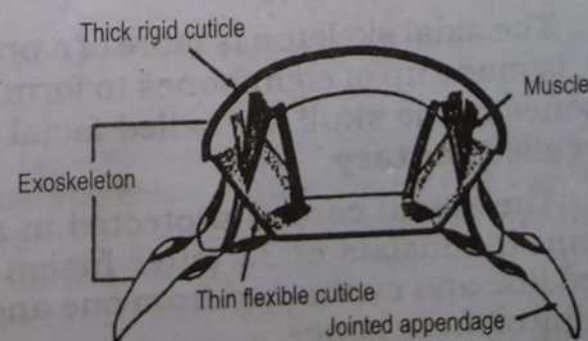


Fig: 2.6 Exoskeleton

exoskeleton is not a single cover but it is divided, by soft flexible joints, into a number of small plates corresponding to the number of segments of the body and of the appendages. Without these joints, movement of the body parts and the entire animals would have been very difficult. This type of exoskeleton protects the animal, gives it its particular shape and helps in fast movement by providing places for muscle attachment on their inner surfaces.

An exoskeleton, though much advantageous, do have a few disadvantages. It limits size of arthropods. Most of the land arthropods and flying insects are small because a heavy exoskeleton of larger animals would seriously limit their movement. Growth is also limited because the exoskeleton is non-living and non-growing therefore as the animal grows it has to shed its exoskeleton and make a new but larger one. This process, called **moulting** (ecdysis), occurs many times till the animal grows to its adult size. After each moult when the newly formed skeleton is soft animal becomes an easy prey for predators because it neither has its armour like protection nor the ability to escape quickly.

3. Endoskeleton:

This type of skeleton lies inside the body. Although found in a few invertebrates like the spicules of sponges and calcareous plates of star fishes, it is mainly the complex skeleton of vertebrates, which is a true endoskeleton.

The endoskeleton in the vertebrates is an internal frame-work of the body being composed of two types of living (rigid connective tissue) materials, the **bones** and the **cartilages**. They articulate with each other at a variety of joints that allow a wide range of movements brought about by the contraction of muscles attached to them. As the endoskeleton of vertebrates is made up of living material, it grows in correlation with the growth of the animal and does not hinder the growth.

4. Human skeleton:

An adult human endoskeleton consists of 206 bones and is divided into an **axial skeleton** which includes the skull, the sternum, the ribs and the vertebrae and an **appendicular skeleton** which includes the pectoral and pelvic girdles and the bones of arms and legs (Fig: 2.7).

A human endoskeleton is about 18% of the total body weight.

5. Axial skeleton:

The axial skeleton is more of a protective nature. Cranium, which is a part of skull, is made up of eight bones to form a brain box to protect the brain. The rest of the bones of the skull are called facial bones. Lower jaw is supported by a single bone called **dentary**.

The spinal cord is protected in a hollow spine (backbone) called vertebral column. It consists of 33 (after fusion 26) bones called vertebrae arranged in a curved line and cushioned from one another by cartilaginous discs preventing the grinding of these bones.

> Though the original number of bones in a human vertebral column in 33 but due to the fusion of 5 hip vertebrae into a sacrum and fusion of all the 4 tail vertebrae into a coccyx the visible number decreases to 26.

The rib cage encloses the chest cavity and protects heart and lungs. Ribs are semicircular bones attached on their dorsal side with the vertebrae and on their ventral with the sternum. The lower two pairs of ribs are called floating ribs because they remain free and are not connected with sternum.

6. Appendicular skeleton:

The movable limbs attached to the axial skeleton constitute the appendicular skeleton which forms a system of levers to provide mobility to the body. A pair of pectoral girdles, at shoulders, hold the arms to the axial skeleton. Each pectoral girdle consists of a **scapula** and a **clavicle**. Each of the human fore-limb (upper limb) contains 30 bones, a **humerus** which forms a ball and socket joint with scapula and two long parallel bones the **radius** and **ulna** at its distal end. The radius and ulna join at wrist with 8 small **carpal** bones, which articulate with 5 **metacarpal** of the palm. From the palm extend the fingers containing 14 small bones called **phalanges** arranged in 5 rows, one row in each finger.

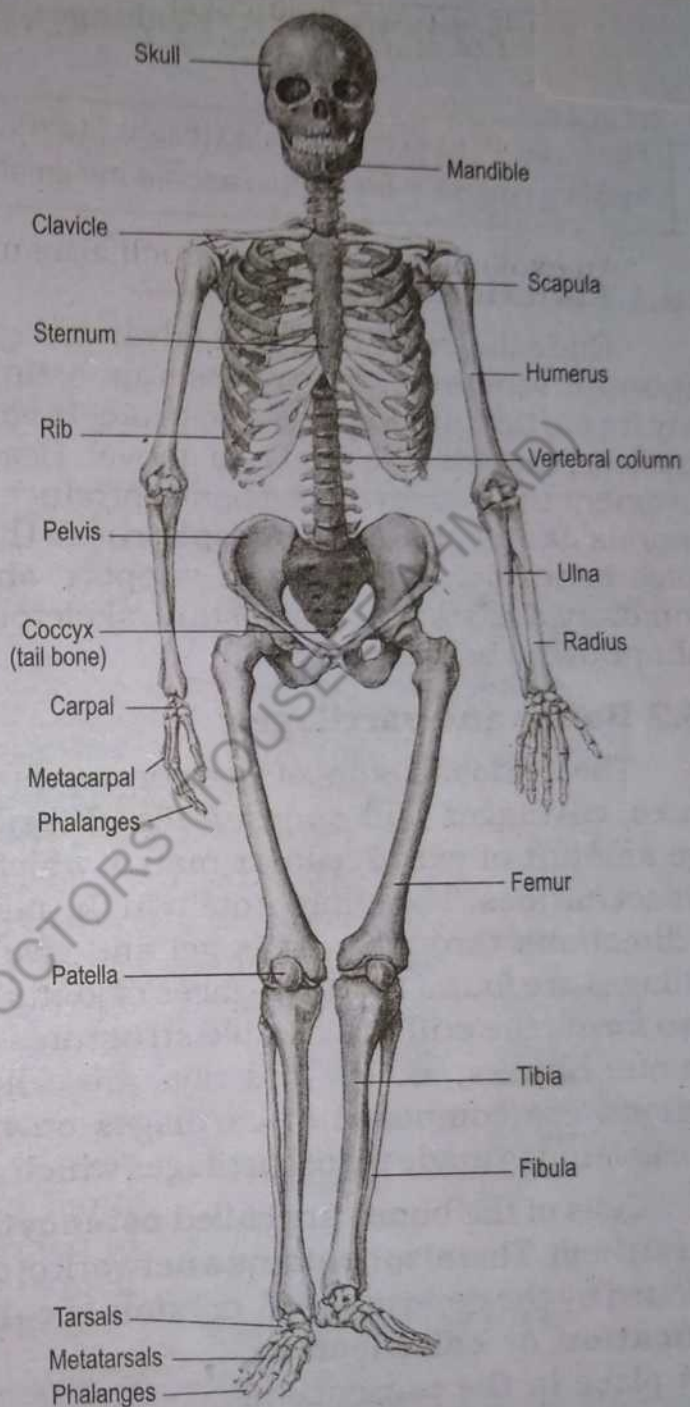


Fig: 2.7
Anterior view of the entire human skeleton

The pelvic girdles serve to attach the legs with the vertebral column at the hip region. Each pelvic girdle called **innominate** bone is formed by the fusion of three bones **Ilium**, **Ischium**, **Pubis**. The bones of leg include a **femur**, in the thigh, connecting the leg with pelvic girdle by a ball and socket joint, two long parallel bones the **tibia** and **fibula** in the shank with a small **patella** bone at the knee joint. There are present 7 small **tarsal** bones in the ankle, 5 long slender bones in the sole

metatarsal and 14 bones the **phalanges** arranged in five rows one row in each of the five toes.

> Femur, the bone of the upper leg (thigh), is the longest and strongest bone in human body. Auditory ossicle in the middle ear are the smallest. They carry sound waves.

2.5.1 Functions of skeleton:

Endoskeleton, the most advanced type of skeletal structure perform many important functions. It provides supporting frame-work for the body, it gives the body its particular shape, it also protects various organs and, in collaboration with muscles, enables the body to move. Besides shape, support, protection, and movement the marrow of the bones produce blood cells and stores and supplies the minerals like calcium and phosphorus to the blood whenever needed. Exoskeleton is also beneficial and provides support, shape and protection in addition to the locomotory assistance. Hydrostatic skeleton helps in movement and maintenance of shape of the body.

2.5.2 Bones and cartilages:

The endoskeleton of vertebrates is made up of two types of connective tissues, cartilages and bones. Cells of cartilages called **chondrocytes**, secrete a large amount of extra-cellular matrix which is a gel like mixture of proteins and polysaccharides. The main protein in the matrix is **collagen** whose fibres run in all the directions through matrix gel and give the cartilage strength and elasticity. Cartilages are found at the surfaces of joints whose bones move against each other. It also forms the stiff but flexible structures like larynx, external ear and tip of the nose etc. Sharks, skates and rays are called cartilaginous fishes because their skeletons are composed of cartilages only. In all other vertebrates embryonic endoskeleton is made up of cartilages which are gradually replaced by bones.

Cells of the bones are called **osteocytes**. They also secrete, a gel like matrix around them. This also contains a network of collagen fibres but unlike cartilages it is hardened by the deposition of crystals of **calcium phosphate**. This process, called **ossification** or **calcification**, takes place in the presence of vitamin 'D' which is necessary for calcium absorption from the blood and milk. Milk, a major part of a child's diet, is a good source of calcium. The protein and mineral salts together make the bones hard and elastic. Without sufficient calcium they remain soft and are hence easily deformed.

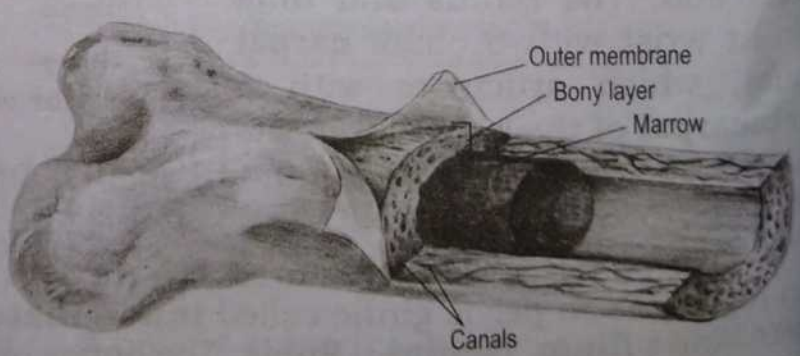


Fig: 2.8
Bones are made of living tissue. Marrow, the soft tissue in the centre of bones, makes blood cells

2.5.3 Joints:

If the skeleton were a single solid piece of bone it might have been stronger but the movement would have been impossible. Instead the skeleton consists of many bones, linked together. The points at which bones connect each other are called **joints** (Fig: 2.9). Many joints are movable and help in the movement of an animal and its parts. Human skeleton has several different kinds of joints. Your hip and shoulder joints are the examples of **ball and socket joint**. In this type of a joint the ball like head of the long bone of thigh or upper arm fits into a cup like socket of the girdle. This joint allows a great deal of movement and thus you can move your arms or leg, in almost any direction even in a circle.

The joints of elbow and knee are **hinge joints**. These joints enable you to move your fore limb and legs (below the knees) back and forth. This movement is similar to the way a door swings at a hinge.

Your elbow has two joints. Rest your elbow on a table with the palm of your hand facing up. Raise your palm towards your shoulder, the **hinge joint** in your elbow allows this movement. Your elbow also has a **pivot joint**, which allows a twisting movement. By moving the pivot joint in your elbow you can rotate the palm of your hand upside down. The skull is also connected to the spine by a similar pivot joint, which allows the side ways movement of the head.

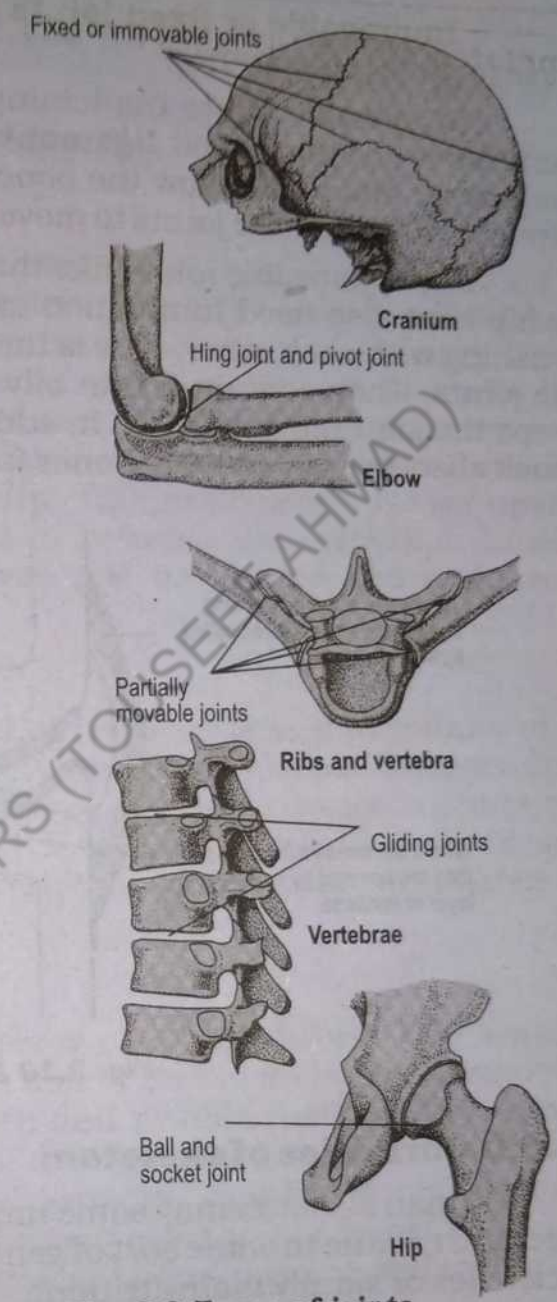


Fig: 2.9 Types of joints

Sliding joints connect the bones that meet at your **ankle** or **wrist**. In this type of a joint bones slide over another to allow movement of your wrist or ankle in many directions.

Vertebrae are linked by **gliding joints**. At these joints the bones move easily over one another in a back and forth manner. Gliding joints make the backbone flexible.

The joints described above are the examples of **freely movable joints**.

Partially movable joints allow a little movement. Your **ribs** are attached with vertebrae by partially movable joints. These joints permit your ribs to move up and down while you breathe.

Some joints fit together tightly like the pieces of a puzzle. These joints are called **fixed joints** because they don't allow the joining bones to move.

Immovable or **fixed joints** connect the **bones of the skull**, in the form a case to protect the brain.

At movable joints the joining bones are held in place by strong straps of connective tissues called **ligaments** (Fig:2.12). Ligaments connect the bones to each other and don't allow the bones to slip and dislocate at a joint. As ligaments stretch, they allow the joints to move.

Highly movable joints like that of elbow or a knee (Fig:2.10) and a shoulder or hip joint also need lubrication and cushioning to prevent the adjoining bones crushing with each other. This is the function of **synovial cavities** present around the joints. They contain a thin oily **synovial fluid** that reduces the friction and keeps the joint moving freely. In addition cartilage pads at the end of bones act as shock absorber and prevent bones from grinding together.

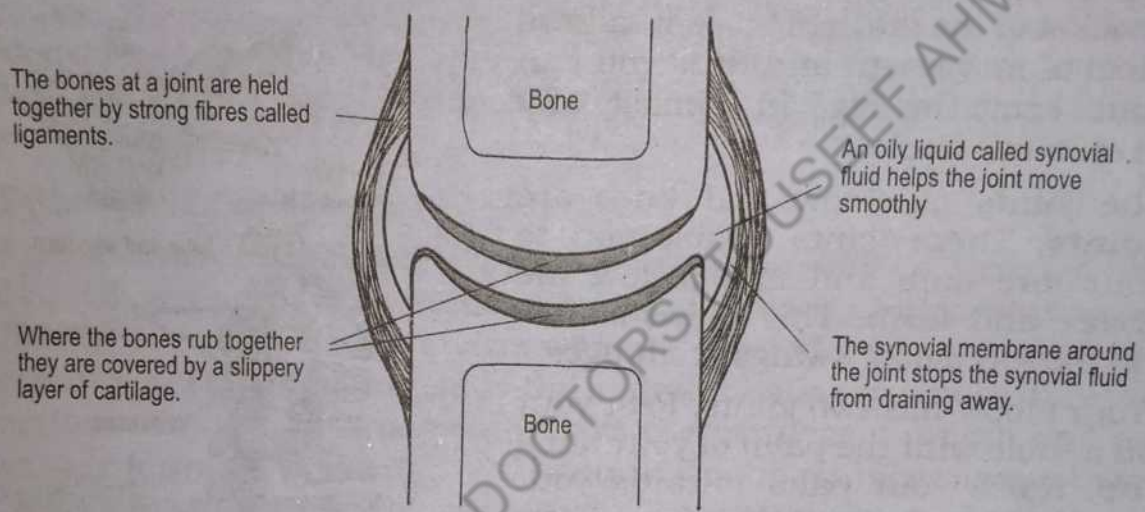


Fig: 2.10 Parts of hinge joint

2.5.5 Deformities of skeleton:

Human skeleton may some time suffer from some deformities. These may be congenital i.e. due to some sort of genetic disorder or may be the result of hormonal deficiencies or simply malnutrition.

Genetic disorders of human skeleton include **cleft palate** in many people; under-development of skull, a phenomenon called **microcephaly** or many types of **arthritis**, in particular, arthritis of joints called **osteoarthritis**.

Hormonal disorders of skeleton are the deformities of bones caused by hormone deficiency. The most common is the **osteoporosis** being far more common in elderly women because level of their **estrogen** secretion falls. The bones, as a result, become porus, thin and weak, consequently easily breakable. Although all the bones are affected, the hip bones, vertebrae and wrist bones become more prone to fractures.

Nutritional deficiency or **malnutrition** in general and deficiency of **vitamin 'D'** in particular decreases the absorption of calcium which results in softening of the bones and hence the distortion of skeleton. This disease is called **rickets**, which deforms pelvis and legs in children hence their legs become bowed.

A simple deficiency of minerals like calcium and phosphorus in the diet leaves the bones soft and deformed and the legs of the affected person become incapable of bearing the weight of his body.

Some of the common skeleton related diseases are as follows:

1. Disc slip:

Vertebrae of our body are provided with **intervertebral discs** which act as shock absorbers. They provide mobility to vertebrae and act as safety devices to avoid the grinding hence wearing of successive vertebrae. Inner cushion like portion of each disc present between adjacent vertebrae is soft and jelly like whereas outer ring is strong and cartilaginous and holds the successive vertebrae together. If, unfortunately, due to a physical trauma the cartilaginous ring of a disc ruptures and displaces, it is called a **disc slip**. This protrusion presses upon a spinal nerve, emerging from the spinal cord in between the vertebrae, causing severe pain and unability to move. Prolonged rest on a hard bed and use of painkillers help repair the damage.

2. Spondylosis:

Spondylosis is a deformity of the joint of two vertebrae particularly of the neck where the space between the two adjacent vertebrae narrows. This results in pressing upon the nerves emerging from the spinal cord and results in severe pain in neck, shoulder and upper limb etc. The pain is relieved by wearing a hard collar around the neck which keeps the affected vertebrae, a bit, apart and hence the pressure on the nerves is released.

3. Arthritis:

It is a condition in which a joint becomes swollen, painful and immovable. It may be hereditary, may be due to a viral infection or due to an injury or sometime only due to aging. In this disease the smooth and flexible cartilage between the bones of a joint is denatured by the deposits of calcium, which makes the cartilages hard. The joints become very stiff and hard to move, and the person becomes crippled. The only remedy is replacement of the affected joints by artificial joints made up of rubber and plastic. Artificial joints are often used to replace stiff hip and knee joints.

4. Sciatica:

It is the severe pain of the hind limb, which occurs when a nerve of the sciatic plexus is being pressed, may be due to a disc slip in the lower abdomen, a trauma or due to a damage to a branch of sciatic nerve. It makes the leg highly painful and virtually immovable. Recovery is very slow and often not complete.

2.5.6 Repair of a broken bone:

Bones though strong enough, sometimes break as a result of trauma or due to their weakening in the old age. Bones are not dead, they are dynamic living tissue and whenever broken, start healing like any other damaged tissue of the body does. A broken bone is said to be a **fractured bone**. After a fracture has occurred, the job of the doctor is only to fix the bone, with or without surgery, in its

normal position. In case of a compound fracture, the bone is realigned by fixing steel screws, rods or plates. This realigned bone is now made immovable for a few weeks by wrapping the affected area into a **plaster**, a **cast of plaster of paris**. By doing so the broken ends of the bone are held together under stress so that the healing takes place in the right position.

2.6 MUSCULAR SYSTEM

A fish swims, an earthworm crawls, a mosquito flies, a kangaroo jumps and people walk. All this is made possible by a **system of muscles**. Muscles are made up of muscular tissue. A muscular tissue is a group of muscle cells. The muscle cells are specialized to perform one unique function; to generate a **pulling force** that is they shorten or contract. Without this contracting or pulling force of the muscles, a skeleton can do nothing more than to support an animal. But the muscle do much more than to move the parts of skeleton. Muscles move eye lids, tongue, beat the heart and pump internal fluid through the circulatory system, propel food through gut, discharge wastes, squeeze out secretion from the glands, maintains gaseous exchange and generate powerful jets of water that propel an animal out of danger. All these actions are called **movements** and are brought about by muscle contraction.

Muscles are present in almost all animals. Even the single celled protoctists have some (non-striated) contracting muscle like fibres. Among the invertebrates the bodies are composed of (smooth) muscles that contract slowly but rhythmically thus bringing about deliberate but slow body movement. Only the vertebrates and arthropods have specialized muscles (striated) and thus can move quickly.

There are more than 600 muscles in a human body and almost half of your body weight is due to muscles.

A man and a woman both have the same number of bones and the same number of muscles

2.6.1 Types of muscles:

There are three types of muscles in a vertebrate body. They are **skeletal muscles**, **smooth muscles** and **cardiac muscles**.

1. Skeletal muscles:

These are the muscles associated with the bones and enable your skeleton to move. Skeletal muscles are **voluntary** in function. They can contract strongly and rapidly but fatigue quickly. Under the microscope, skeletal muscle cells look striped, hence they are also called **striated** muscles. These muscles are made up of protein filaments.

Some skeletal muscles are directly attached to the outer covering of the bones whereas a few terminate into a tough non-elastic tissue called **tendon**, (Fig: 2.12) which connect these muscles to the bones. When the muscle contracts it pulls on the tendon which in turn pulls the bone causing it to move. Muscles must attach at two points for movement to occur. The attachment to the stationary part is called **origin**. The attachment to the movable part is called the **insertion.**

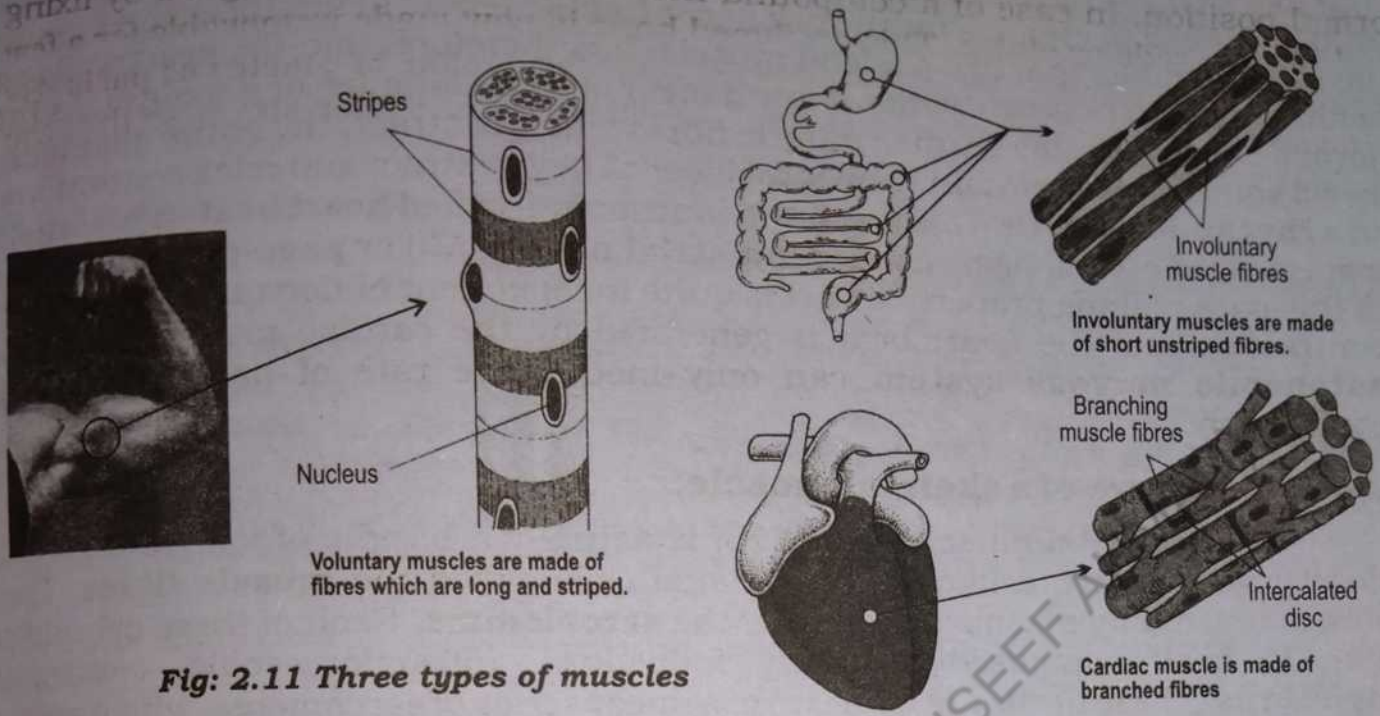


Fig: 2.11 Three types of muscles

2. Smooth muscles:

Smooth muscles are structurally the simplest of all muscle types. Unlike skeletal muscles, smooth muscles are non-striated. They consist of long spindle shaped **uni-nucleated cells** that are usually arranged in sheets that surround the body's hollow organs. Smooth muscles are **involuntary** that is their contraction is not under the conscious control of animal itself, instead they are automatic being controlled by autonomic nervous system.

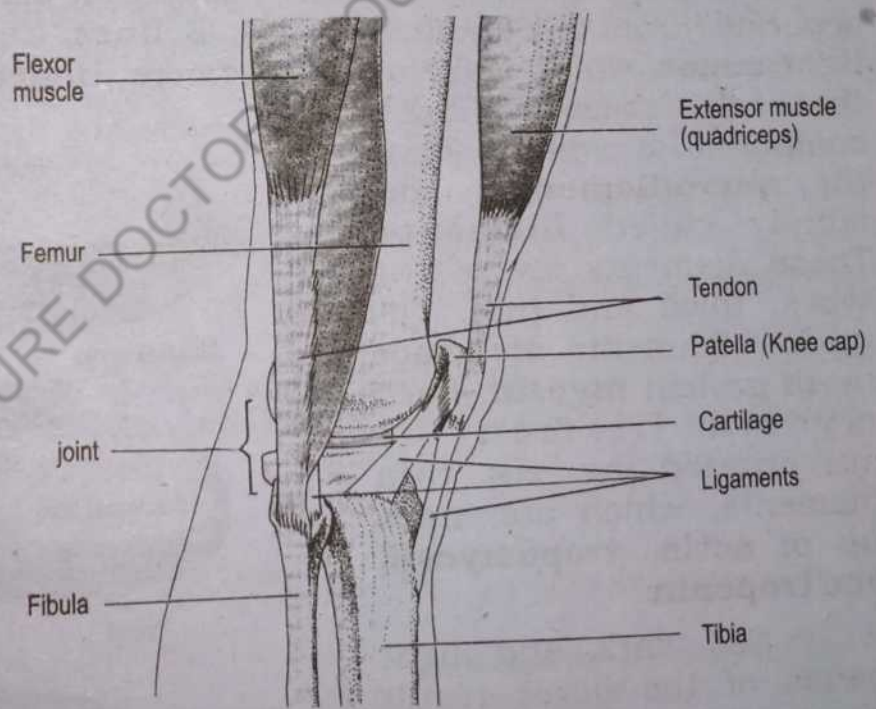


Fig: 2.12 Joints, ligaments and tendons

Smooth muscles push the food through the digestive tract, they empty your urinary bladder, and they control the diameter of your blood vessels, the diameter of the pupil of your eye and the state of erection of hair of the skin.

3. Cardiac muscles:

Cardiac muscles are so called because they only form the muscular **walls of the heart** of man and most of the vertebrates. These muscles have a unique combination of properties. Like smooth muscles cardiac muscles are **involuntary**

but like skeletal muscles they are **striated**. They are uninucleated or binucleated and branched to create a meshwork of contractile tissue hence their fibres cannot be separated like that of a skeletal muscle. It is therefore, that the heart walls can withstand high pressure without any danger of being fatigued or damaged. As they form a meshwork, the cardiac muscle fibres when contract, the entire chamber of heart squeezes to maintain the flow of blood. They contract and relax continuously in a **rhythmic pattern**. This rhythmic contraction, called **heart beat**, is initiated in a specialized area of heart called **sino-atrial node** (SAN) or **pace-maker**. Because of this pace making property, heart is quite independent of nervous system for its contraction and the heart beat is generated by the cardiac muscle itself. The **autonomic nervous system** can only modify the rate of pace maker cells contraction.

2.6.2 Structure of a skeletal muscle:

Each skeletal muscle (Fig: 2.13) is actually a bundle of long and parallel closely packed thread like multinucleated cells called the **muscle fibres**. Each fibre is covered by plasma membrane, the **sarcolemma**. Each of these cylindrical fibre is itself composed of many individual, ultramicroscopic, contractile **myofibrils**. These fibrils are made up of a linear series of sarcomeres, which are the actual units of a striated muscle tissue that contract. Adjacent sarcomeres are separated from one another by dark **'Z' lines**. Between the 'Z' lines are **dark** and **light zones**, which make up a sarcomere. Under electron microscope, it is seen that each of these myofibril is composed of smaller parts the **microfilaments**, more simply called **filaments**. These filaments are of two types, thick and thin. The thicker filaments are made up of protein **myosin**. Each myosin filament is surrounded by six thin filaments, which are made up of **actin**, **tropomyosin** and **troponin**.

The dark and light bands of the fibres result from a regular overlapping pattern of these thin and thick filaments. Each sarcomere has a pair of lightly staining **I-bands** located at its outer edges, a more darkly staining **A- bands** are located between the outer **I-bands** and a lightly staining **H-zone** is located in the centre of A-

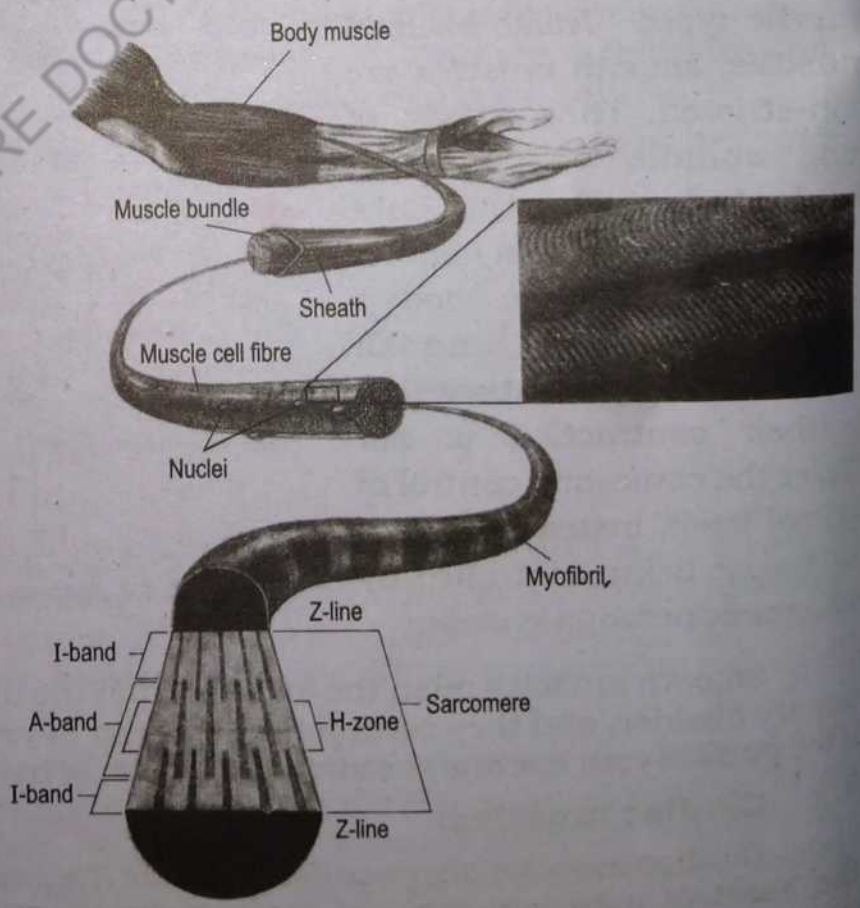


Fig: 2.13 Structure of skeletal muscle

band. The I-band contains only the thin filaments, the H-zone has only thick filaments and the part of A-band on either side of H-zone represents the region of overlapping and contains both thin and thick filaments and hence look darker. The thick filaments have cross bridges, which are attached to the actin filaments during muscle contraction.

2.6.3 Mechanism of contraction of skeletal muscle:

It is a matter of common observation that whenever a muscle works it contracts. When a muscle contracts it becomes **shorter** and **thicker**. The way the muscles become shorter during contraction has been investigated for many years and a number of explanations were offered. The most widely accepted hypothesis has been proposed by **Huxley**, which is based on his electron microscopic observations that whenever a muscle contracts the sarcomeres shorten and the width of dark and light bands changes. This important clue led Huxley to present his **sliding filament theory** of muscle contraction. According to his explanation, the thin filaments of a muscle fibre move together by sliding over thick filament. This is like sliding the fingers of your hand between the fingers of the other hand. The sliding over of the filaments is the reason that the muscle gets shorter and thicker. How does this happen was a mystery until the discovery of the **bulbous heads** projecting from the ends of myosin filament, which act like **cross bridges** to hook into special sites on actin filaments (Fig:2.14). Whenever a nerve impulse is received the myosin cross bridges hook into thin filaments and pull them towards the centre of sarcomere. The bridges break immediately and reform at other (posterior) places on actin. A wave (series) of these small moves cause the thin filaments to slide over (to be pulled over) the thick filament. The filaments do not contract themselves but slide over each other to shorten the muscle fibre. This is like rowing by a team or like pushing the cloth backward by the teeth of a sewing machine.

A fully contracted sarcomere can shorten by 35% of its total length. Each cross bridge repeats its bending movement 50-100 times within a fraction of second or several hundred times each second.

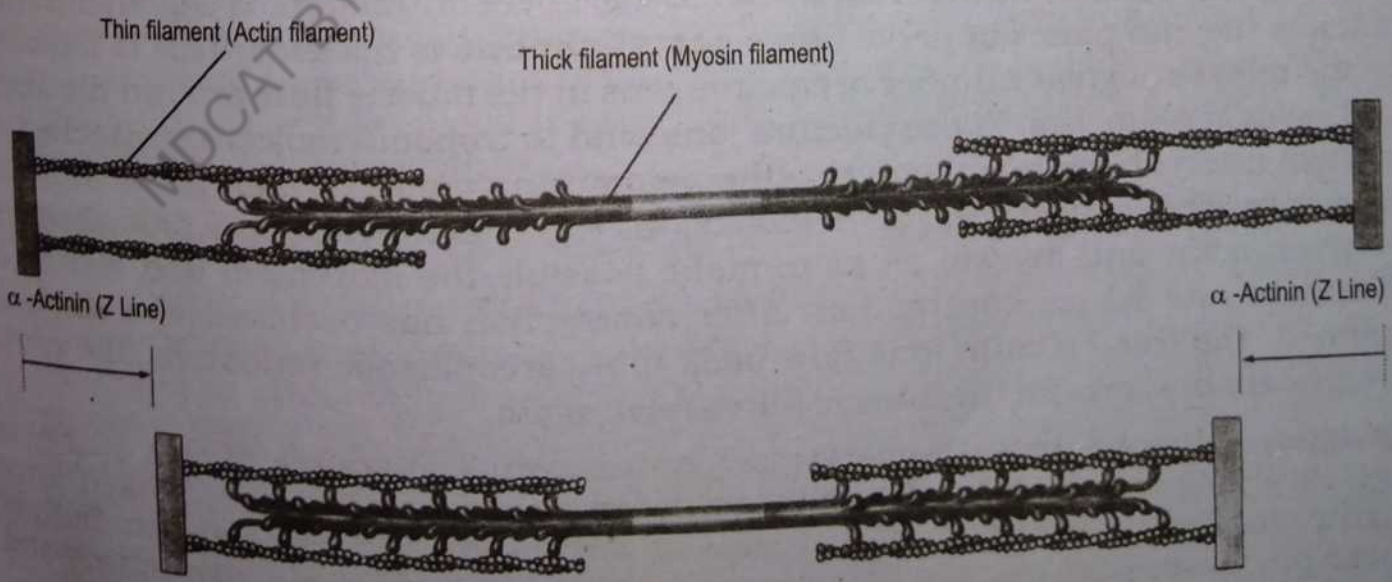


Fig: 2.14 The mechanism of muscle contration

2.6.4 All or no response:

Once an impulse reaches a muscle fibre, there is an all or no-response; either the muscle contracts fully or it does not contract at all, there is no partial contraction for a given fibre. Further more all the contractions are of the same intensity. How come then a muscle can contract to a greater or lesser degree? The strength of contraction depends on how many **motor units** are contracting. "A motor unit is a set of all the muscle fibres innervated by the branches of a single neuron and a single muscle is made up of many motor units". The more motor units contract the greater is the contraction. As a result our movement can be very tender and precise or very forceful. A ball can be thrown very forcefully towards a batter (batsman) in cricket or can be tossed very gently to a child.

Human eye muscles contract in 0.01 seconds

2.6.5 Control of muscle contraction:

The contraction of a muscle depends upon three factors (a) nerve impulse (b) energy and (c) calcium ions.

Muscles are stimulated to contract by **nerve impulses** (messages from the CNS) that travel along the motor nerves from brain or spinal cord. The muscles are so dependent on nerve impulses that they not only stop contracting but degenerate if their stimulant nerve damages or is cut away, as the case is with polio infection.

Muscles also need **energy** for contraction. Energy required for muscle contraction comes from food through some intermediate compounds. These intermediate compounds are glycogen (made up of many molecules of glucose) and creatine phosphate. The energy from food is stored in muscles in the form of glycogen. It is transformed from glycogen to creatine phosphate and finally to ATP where it is stored and is readily available for use of muscle. Creatine phosphate (CP) serves as muscle reserve of high-energy phosphate continually replenishing the ATPs consumed during muscular activity.

Calcium ions, which are stored in abundance in sarcoplasmic reticulum play very important role in initiation of muscle fiber contraction. When an impulse reaches the end plates of nerve fibres **acetyl-choline** is released. This is followed by the release of great number of calcium ions in the muscle fibre around the actin and myosin filaments. These calcium ions bind to troponin molecules attached at regular intervals with tropomysin (the actomysin complex inhibitor) of the thin filaments. This exposes the sites (hooks) for the attachment of the cross bridges between actin and myosin so as to make possible the movement and sliding of filaments and hence contraction. After contraction has occurred and impulse stopped, the free calcium ions flow back into sarcoplasmic reticulum, the cross bridges are broken and the muscle fibres relax again.

Fatigue: Muscles require energy for contraction. The source of this energy is muscle glycogen, which breaks up into glucose molecules. Glucose is broken down further to liberate energy by the process of respiration and fermentation. Both of these processes take place in the presence and absence of oxygen, respectively and are, therefore, called aerobic and an aerobic respiration.

During a heavy or prolonged exercise when enough oxygen is not available muscle cells receive supply of ATP through **fermentation** also called **anaerobic respiration**. During fermentation glucose is converted into **lactic acid** instead of carbon dioxide and water as the case is with normal **aerobic respiration**. This accumulation of lactic acid in the muscle which is poisnous and in high concentration dangerous. Hence the bearer feels a pain which produces a tiring condition of the muscle known as **muscle fatigue**. When this heavy exercise stops heavy breathing continues to supply the excess oxygen to the fatigued (tired) tissues, which now break lactic acid into water and carbon dioxide or convert it into glycogen. Once lactic acid is removed, the fatigued condition of the muscle is over. The amount of oxygen needed to remove lactic acid from the tired muscle is called **oxygen debt**. The more lactic acid present the greater is oxygen debt.

Active and constant use of muscles makes them stronger whereas complete immobilization makes them weaker, and subject to fatigue soon.

2.6.6 Abnormal Muscle Contractions:

Whenever the conditions necessary for a muscle contraction are not fully met with its contraction becomes abnormal. **Tetany** and **muscle cramps** are the common abnormal muscle contractions.

1. Tetany:

Tetany is a **sudden involuntary contraction** of striated muscle, which is caused by low level of calcium in the blood. It excites neurons which triggers muscle twitching rapidly even before the actin and myosin filaments of a muscle fibre had a chance to return to their normal resting condition. Hence the muscle fibres are held under a constant contraction. Because of a high level of stimulation the calcium ions are not removed from the sarcoplasm and the contractile machinary thus keep on generating maximum tension. This condition is called **tetany**. Tetany of the respiratory organs if not treated immediately may prove fatal.

2. Cramps:

It is also a type of tetanic contraction, which is commonly called a **muscle pull**. It usually occurs in a limb's muscles. It occurs due to dehydration, electrolyte imbalance or a low blood sugar level, particularly, after a heavy exercise. Sportsmen are more prone to it.

2.7 ARRANGEMENT OF SKELETAL MUSCLES FOR SKELETAL MOVEMENT

Skeletal muscles work in pairs, with one muscle working against the other. One muscle of a pair contracts to bend a joint, the other muscle of the pair contracts to straighten the joint. Such a set of muscles is called **antagonistic muscles** (Fig: 2.15). The skeletal muscles must work in opposing pairs because muscles only works by contracting that is they can only pull, they cannot push. If one set of muscle pulls on a tendon to bend a joint, another set of muscles must pull on a different tendon to straighten the same joint. Combinations of various muscles permit the controlled movement of a joint in several directions.

The **biceps** and **triceps** is a pair of antagonistic skeletal muscles in your upper arm and are connected to the bones of your arm by tendons. When biceps contract your arm bends at **elbow joint**. The contracted biceps feel firm and tight. At the same time triceps relax and feel soft. In order to straighten your arm triceps contract and biceps relax. Muscles that bend the joints (in this case the biceps), are called **flexors** whereas the muscle which opens or straightens a joint (the triceps in this case), are called **extensors** (Fig: 2.15).

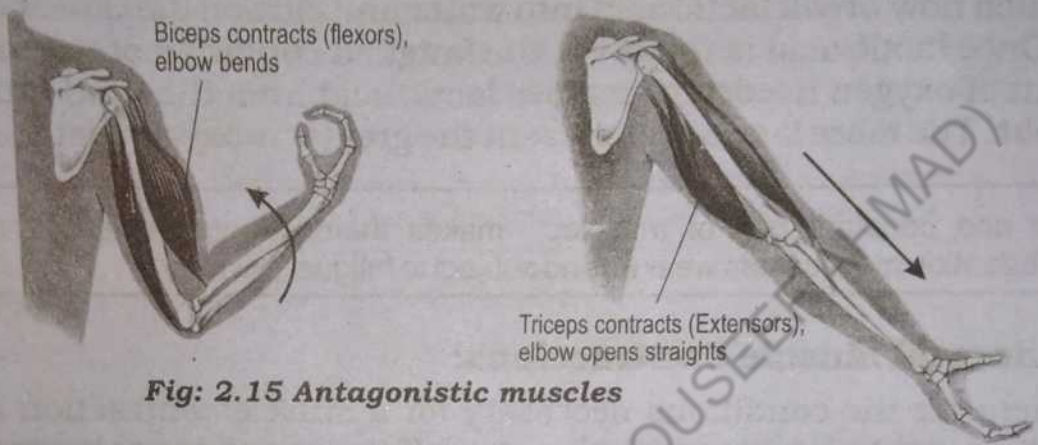


Fig: 2.15 Antagonistic muscles

2.7.1 Movement of shoulder joint:

A shoulder joint is a synovial joint with a ball and socket movement. This joint is formed by the articulation of the glenoid cavity of scapula and head of the humerus bone and is thus also called **gleno-humeral** articulation. Though structurally it looks a weak joint because the glenoid cavity is too small and shallow to hold an almost four times larger head of the humerus in place yet it enjoys the great freedom of mobility and stability. This wide range of stability and mobility is due to laxity of its cartilaginous capsule, shallow glenoid cavity and many sets of antagonistic muscles which make the movement of the arm possible in each and every direction. **Protractor** and **retractor** muscles move the arm in forward and backward direction; **abductor** and **adductor** muscles allow the arm to move away from the body and towards the body and **rotator muscles** (Fig:2.16) help the arm to rotate in all the directions even in a circle.

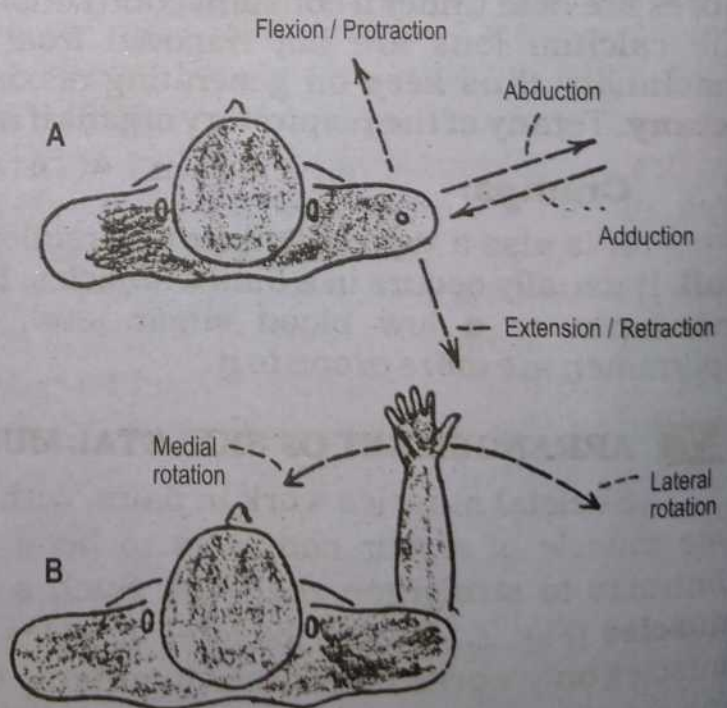


Fig: 2.16
Planes of movements of the shoulder joint

Ball and socket joint of the shoulder allows more movement than any other joint of the human body.

2.8 LOCOMOTION

Locomotion in various organisms takes place in a variety of ways but is brought about by different organs. Although *Amoeba*, earthworm and snake apparently look crawling but the organs involved are totally different. Similarly a Paramecium and a fish both swim; Paramecium swims by its cilia whereas the fish uses its muscles and skeleton.

2.8.1 Locomotion in Protozoa:

Locomotion in Protozoa, a group of protoctists is usually carried out by appendages like outgrowths of the cell body. These are of three types i.e. **pseudopodia** in *Amoeba*, **cilia** in *Paramecium* and **flagella** in *Euglena*.

1. Locomotion in *Amoeba*:

Locomotion in *Amoeba* is called amoeboid movement (fig:2.17) and takes place by the help of **pseudopodia** which are temporarily formed finger like projections of cytoplasm. A pseudopodium, formed in the direction of movement, attaches to the substratum and by a contractile process whole cytoplasm flows into it. A fresh pseudopodium is formed farther off in the same direction and cytoplasm is now pulled into it. The Amoeba thus moves in that direction by continuously repeating this process. **Amoeboid movement** depends upon alternate change of cytoplasm into a fluid like **sol** and a jelly like **gel** form.

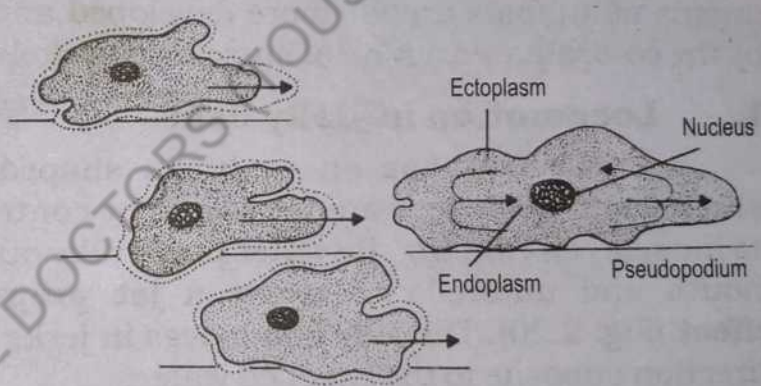


Fig: 2.17 Amoeba- Amoeboid movement

2. Locomotion in *Paramecium*:

The body of a Paramecium is covered all over by a large number of short thread like extensions, of plasma membrane, called cilia. The locomotion in paramecium takes place by the beating of these cilia and hence is called **ciliary movement** (Fig:2.18). Locomotion is brought about by alternate **power strokes** and **recovery strokes**. A powerful backward power stroke of hundreds of these cilia push the body forward.

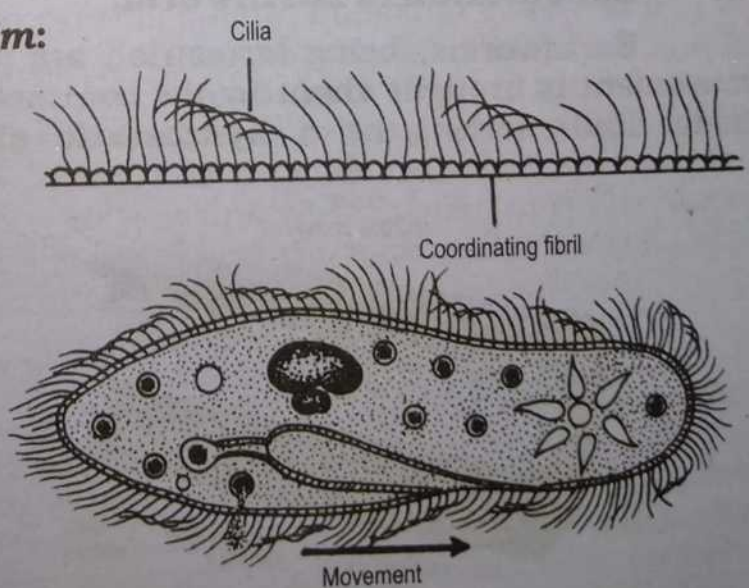


Fig: 2.18 Paramecium- Ciliary movement

3. Locomotion in *Euglena*:

The locomotory organelles in *Euglena* are flagella and the movement brought about by flagella is called **flagellary movement** (Fig:2.19). The flagella are structurally and functionally similar to the cilia with the difference that the flagella are very few, if not single, relatively larger in size and beat in a whip like fashion. Locomotion is brought about by the alternate right and left power strokes and recovery strokes.

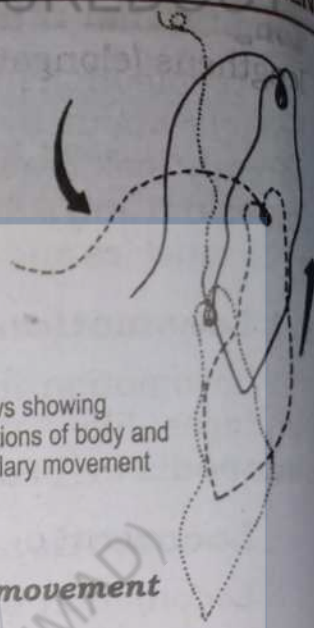


Fig: 2.19
Euglena-Flagellary movement

2.8.2 Locomotion in Animalia:

Locomotory organs of animals are built on a quite different plan than those of the protoctists. Instead of being appendages of a single cell, the locomotory organs of animals are far more developed and work by the co-ordinated action of muscles and skeleton.

1. Locomotion in Jelly fish:

A jelly fish has an umbrella shaped body which floats freely on water or swims by contracting its muscle cells forcing the water powerfully out of its mouth and umbrella to create a **jet propulsion effect** (Fig: 2.20). The jelly fish moves in jerks in the direction opposite to the expelled water.

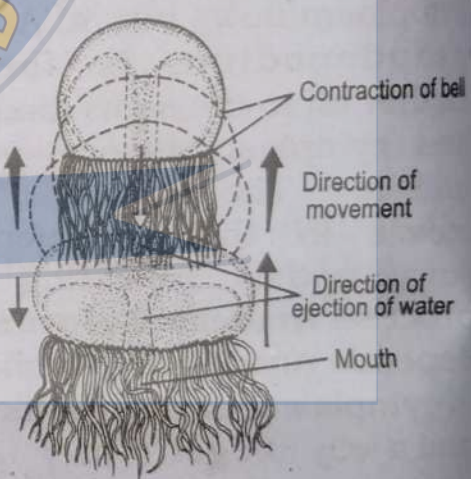


Fig: 2.20 Jelly fish-movement by jet propulsion

2. Locomotion in Earthworm:

Earthworms, being terrestrial, are adapted to locomotion in soil. Their movement is brought about by the contraction of two sets of muscles and their body fluid, serving as a **hydrostatic skeleton** (Fig: 2.21) Contraction of

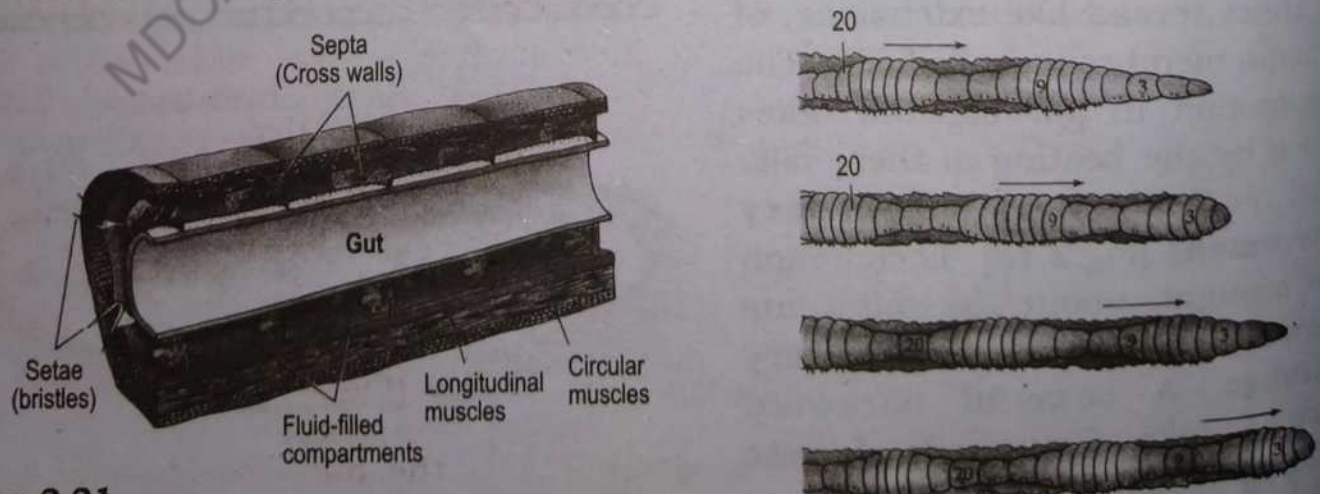


Fig: 2.21
Earthworm: body plan and pattern of locomotion

Longitudinal muscles shortens the body and contraction of **circular muscles** lengthens (elongation) the body. As a result of interaction of muscle contractions and compressed body fluid an earthworms crawls.

In addition bristles called **setae** extending from the body wall in each segment grasp the soil functioning as hold fast to take the grip of the soil.

3. Locomotion in Snail:

Locomotion in snail, like other molluscs, takes place by a specialized organ, the **foot** (Fig:2.22).Snail moves by the contractions of muscles underside the foot. These contractions are brought about under the influence of hydrostatic pressure of the body fluid. The waves of contraction from front to rear push the animal forward. This movement is made easy by a slimy secretion of the mucuous gland poured in front of the foot and animal virtually slips forward. This gives rise to the familiar shining tract left by a moving snail.

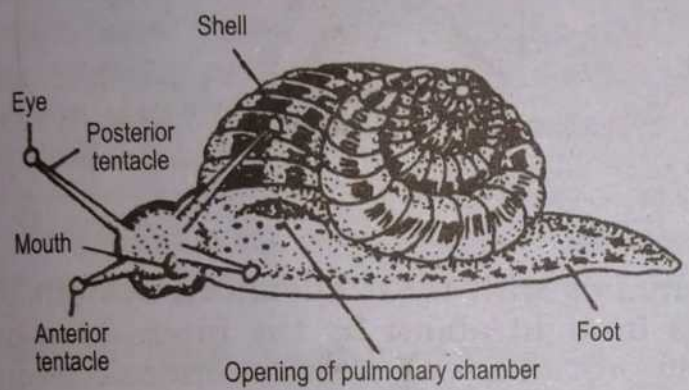


Fig: 2.22 A land snail

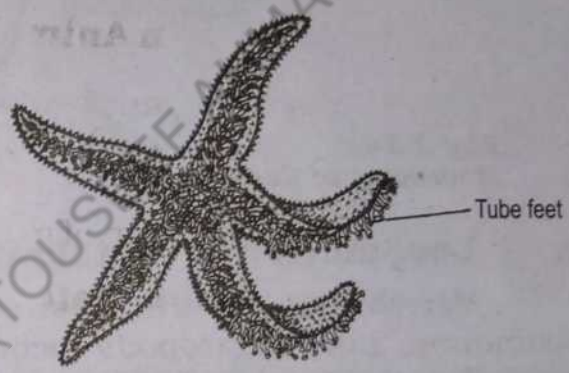


Fig: 2.23 Ventral view of star fish showing tube feet

4. Locomotion in Star fish:

In star fish locomotion is controlled by a special **water vascular system**. Water is drawn into the body through a small opening in the central disc and is passed through a ring canal to five radial canals one running along each arm. Along each of these canals a large number of hollow, muscular **tube feet** (Fig:2.23) are present. The upper part of a tube foot, connected with the canal, is a bulb shaped **ampulla** whereas its bottom part is a **sucker**. When ampullae contract water forces the tube feet to lengthen and suckers become attached to an object. When sucker muscles contract the water is pushed back into the ampullae, making the tube feet flaccid, losing the grip and the star fish is pulled forward. Using its hundreds of feet a star fish creeps along the rock and other solid objects in the sea. Using its arms, it can also swim in water.

5. Locomotion in Cockroach:

Locomotion in arthropods is brought about by the interaction of the **muscular** and **exoskeletal system** of its jointed legs. The legs act as efficient levers and make the movement much more fast and swift. In cockroach muscles are attached to the inside of exoskeleton of legs (Fig 2.24). These antagonistic muscles work in opposition to one another. Contraction of these **flexor** and **extensor** muscles move the appendages and the animal. The swift and fast movement of an arthropod makes it better adapted to catch a prey and escape a predator; a key to their success which resulted in their wide spread distribution.

Cockroach like many other insects is blessed with wings for flight adding a lot to their mobility.

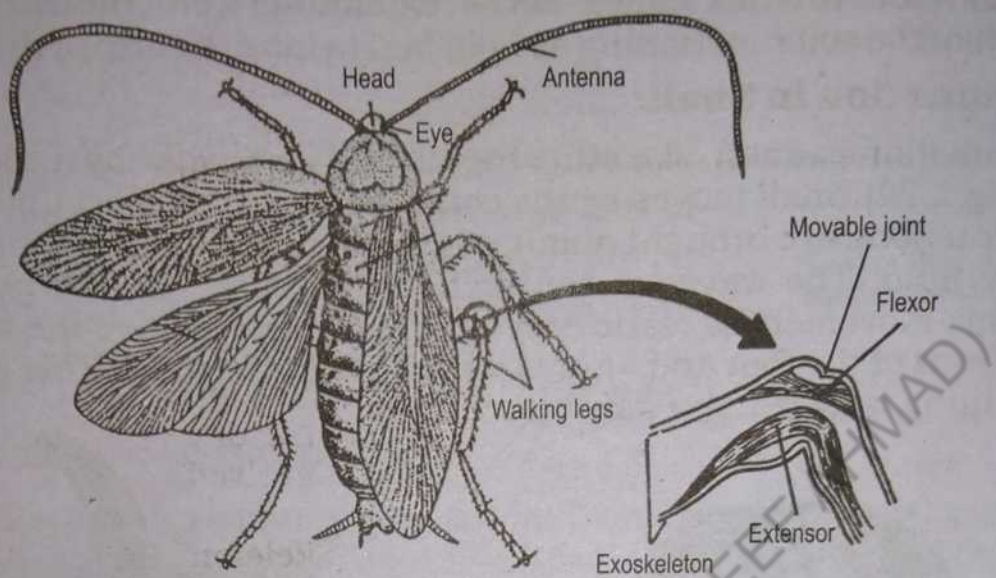


Fig: 2.24
Movement of Cockroach

6. Locomotion in Vertebrates:

Vertebrates are the most evolved animals with most advanced system of locomotion. Like arthropods locomotion is brought about by the interaction of **muscular** and **skeletal systems** but being provided with a living endoskeleton they are at advantage.

The basic skeletal plan of all the vertebrates is the same. It is, however, modified according to their habitat and mode of locomotion. Fishes living in water swim freely by the undulating movement of their body and tail which is possible due to their flexible vertebral column. Balancing and steering is assisted by paired and unpaired fins.

All the terrestrial vertebrates are **tetrapods** being provided with four legs with the same structural plan. These legs are the principal locomotory organs in all the tetrapods.

The **amphibians**, the first land vertebrates, are thought to have evolved from the ancient lobed fin fishes. Like their ancestors the legs of amphibian spread out of the body so most of them virtually drag their body on the ground.

Early reptiles also had the same type of a posture with their legs spreading out of the body in the same plane. Later reptiles, however, showed the trend towards bringing their legs beneath their body. This trend reached its peak in birds and mammals where legs came right below the body serving as props. This is not only the most efficient way of supporting the weight of the body but also walking or running on the land. Birds and anthropoids (Man, Apes etc.) became bipedal and started walking and running on their hind limbs keeping their forelimbs free. In birds the fore limbs are modified into wings for flight and in anthropoids fore limbs serve for feeding, holding or for other activities.

2.9 EVOLUTION OF SKELETO-MUSCULAR SYSTEM

The skeleton within your body can be traced through a series of fossils to the skeleton of primitive fishes that lived some **400 million years ago**. These fishes were covered with bony plates. All these bones disappeared during the course of evolution though some of the derivatives of these bones are seen in recent vertebrates. The bones in our limbs are not that old. They first appeared in the ancient amphibians soon after the vertebrates made their way onto the land. The bones of these limbs were derived from the bones of the fins of lobed fin fishes from which the amphibians evolved. The amphibian limb plan underwent gradual modification with the evolution of reptiles, birds and mammals.

The skeletal system arose from primitive fishes whereas the muscles of vertebrates are far more older in origin. Actin and myosin, the major proteins of the vertebrates muscle tissue are found virtually in all the eukaryotes including protoctists, hence they might have appeared very early in the course of animal evolution. As the vertebrates moved out of water, their skeleton evolved along many diversified branches according to the need of their environment and mode of their locomotion. As the muscles are co-related with the type of skeleton and its movement they evolved accordingly.

> Muscle tissue is present throughout the kingdom animalia; bones are unique to vertebrates.

KEY POINTS

- Movement is a response shown by a living organism towards stimulus.
- As living organisms grow in size, they need support to maintain their shape and posture to stand erect for balanced, fast and rhythmic movement.
- In young stem, the anatomical arrangements are, outer most epidermis, beneath it cortex and in the centre stele.
- Stem depends for mechanical support on turgidity of parenchyma, thick walled collenchyma and sclerenchyma, and stele the central core of vascular bundles.
- Parenchyma are thin walled cells with large vacuole and intercellular spaces.
- Collenchyma has also thin walled, elongated living cells with irregular thickening at their edges.
- Sclerenchyma are thick walled hard tissues on maturity they become dead.
- Tissues formed by the activity of vascular cambium and cork cambium are called secondary tissues which increase the primary girth and is called secondary growth.
- There are two main types of movements in plants autonomic movement due to internal stimuli and paratonic movement due to external stimuli.
- The skeleton is the frame of a body. It supports and protects the body and enables it to move.

- Hydrostatic skeleton, exoskeleton and endoskeleton are the three types present in animals.
- All the vertebrates have an endoskeleton. Human endoskeleton is a living flexible frame work being made up of 206 bones.
- Arthropods have a rigid non living exoskeleton sub divided by soft joints.
- Joints can be affected by arthritis.
- Muscles work with bones to produce movements and locomotion.
- Muscles work by contracting. The muscles are of three kinds; skeletal, smooth and cardiac.
- Striated muscles are called skeletal muscles because they move the skeleton to bring about locomotion. They work in pairs called antagonistic pairs.
- Sliding filament theory states that actin and myosin filament slide over each other to shorten sarcomeres thus contracting the muscle.
- Contraction of muscles is brought about by the nerve impulses, energy supply and transfer of calcium ions.

EXERCISE

1. Choose the correct answer:

i) Movement in plant due to unequal growth on two side of organs is
a) Nutation b) Curvature movement
c) Nastic d) Tropic.

ii) Growth movement caused in response to gravitational stimulus
a) Nutation b) Growth movement
c) Geotropism d) None of these.

iii) Phototropic curvature is due to light effect on the distribution of hormone.
a) Gibberellin b) Auxin
c) Ethene d) Abscisic acid.

iv) The movement of plant organs in response to touch stimulus:
a) Chemotropism b) Geotropism
c) Thigmotropism d)Hydrotropism

v) Increase in diameter of plant due to activity of vasular cambuim and cork-combium.
a) Primary-growth b) Secondary-growth
c) Both "a" and "b" d) None of them

vi) Skeleton is totally absent in
a) Sponge b) Star fish
c) Fish d) Amoeba

vii) The exoskeleton in arthropods is made up of
a) Bones b) Cartilages
c) Chitin d) Calcium

viii) Total number of bones in a human's skeleton is
a) 205 b) 206
c) 207 d) 208

ix) Bones of the ankle are called
a) Tarsals b) Metatarsals
c) Metacarpals d) Carpals

x) Bones of the skull are joined by
a) Fixed joints b) Sliding joints
c) Pivot joints d) Hinge joints

xi) The number of muscle in a human body is about
a) 300 b) 400 c) 500 d) 600

xii) Each myosin filament is surrounded by
a) 4 actin filaments b) 6 actin filaments
c) 8 actin filaments d) 12 actin filaments

2. Write detailed answers of the following questions:

i) How higher plants stand erect in air and their soft organs remain firm?

ii) What is secondary growth and what is the significance of secondary growth?

iii) Describe various types of skeletons found in animals. Discuss the advantages and disadvantages of each type.

iv) What is a joint? Name different types of joints found in vertebrates.

v) How many bones a human skeleton has? Describe the position and function of important bones.

vi) What is a skeletal muscle? Describe the structure of a skeletal muscle.

vii) What are antagonistic muscles? Name the different sets of such muscles. How do they move the shoulder joint in all the directions?

viii) Describe the various modes of locomotion in protozoan protoctists.

ix) How does a jelly fish, an earthworm and a star fish move?

3. Write short answers of the following questions :

i) Why does wilting of leaves take place in hot summer days?

ii) How does the exposed tissue of cortex become protected when primary epidermis fall off in stem?

iii) How girth of stem increases from year to year?

iv) How young stem gives mechnical support to plant body?

v) Why leaves of " touch- me- not " closed down on touching?

vi) Write five functions of skeleton.

vii) How does a muscle become fatigued?

viii) Where does a muscle receive the energy from to contract?

4. Define the following terms :

i) Stimulus	ii) Turgor pressure	iii) Lenticels
iv) Cambium	v) Photonasty	vi) Haptonasty
vii) Phototropism	viii) Geotropism	ix) Chemotropism
x) Hydrotropism	xi) Thigmotropism	xii) Annual rings
xiii) Skeleton	xiv) Chondrocytes	xv) Joint
xvi) Osteocytes	xvii) Hydrostatic skeleton	xviii) Tetany

5. Distinguish between the following :

i) Vascular cambium and cork-cambium

ii) Heart-wood and sap-wood

iii) Tendon and ligament

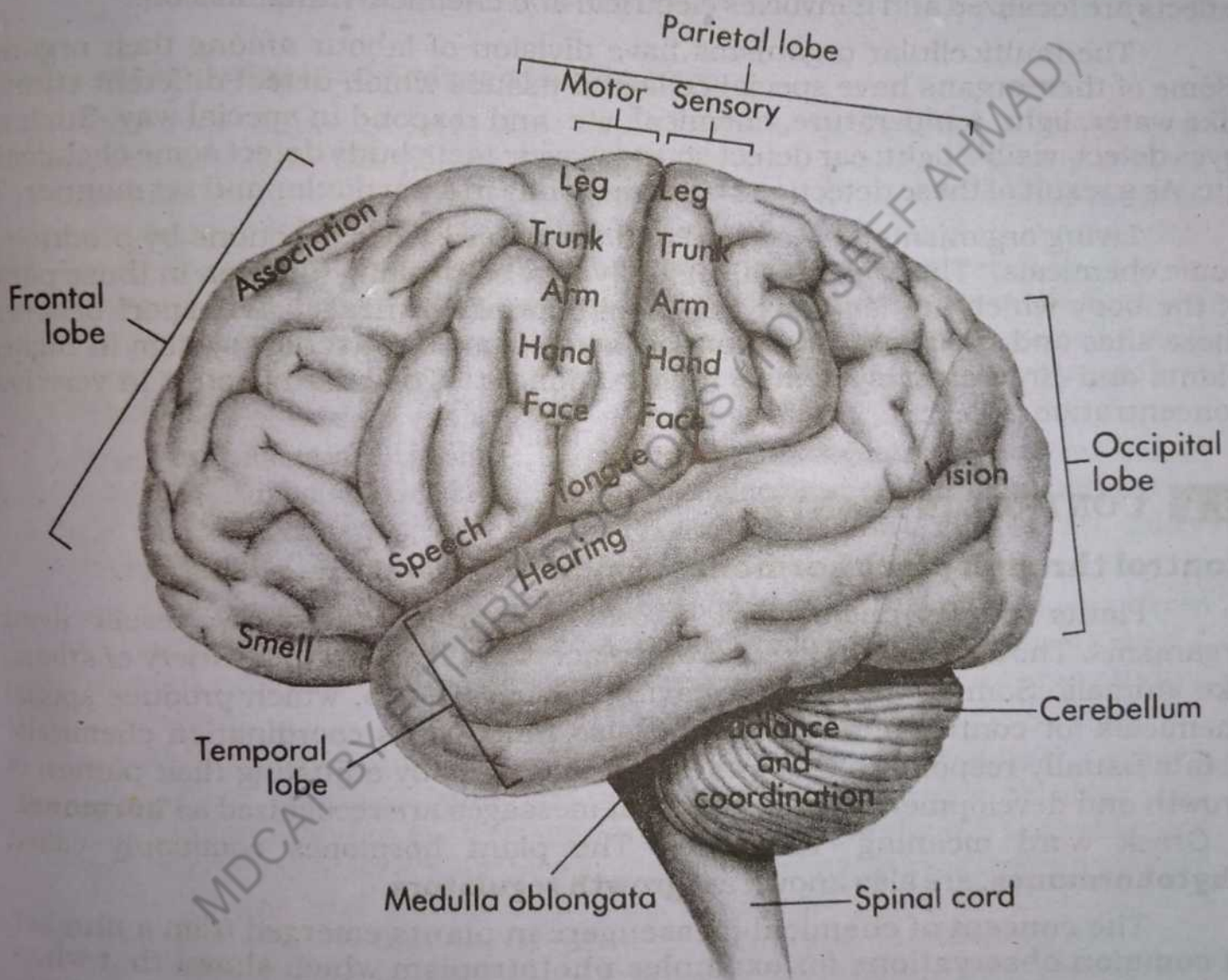
iv) Bone and cartilage

v) Exoskeleton and endoskeleton

vi) Thigmotropism and haptonasty

vii) Skeletal and smooth muscle

COORDINATION AND CONTROL



The complex life processes performed by living organisms, in a coordinated manner, depend upon precisely controlled mechanisms. In the following discussion, the mechanisms of coordination have been discussed in various organisms.

All living organisms have a characteristic feature of irritability or sensitivity and they respond to external and internal stimuli. The responses and needs of the living body resulted in a number of metabolic processes, which are interwoven. Some of these metabolic functions are carried out at the same time or one after the other. They require some degree of internal coordination and control to ensure the maintenance of steady state and survival of the organism.

There are two major types of control mechanisms found in living organisms. One is the **chemical control** mechanism, which is slower in action. Its effects are diffused and rely on chemical transmission through the circulatory system or diffusion process. The other mechanism of control and coordination is **nervous control** mechanism, found only in multicellular animals. It is faster in action, its effects are localized and it involves electrical and chemical transmission.

The multicellular organisms have division of labour among their organs. Some of their organs have special cells and tissues which detect different stimuli like water, light, temperature, chemical, etc. and respond in special way. Such as eyes detect visible light; ear detect sound waves; taste buds detect some chemicals etc. As a result of these detections body responds in a particular and set manner.

Living organisms also control and coordinate their functions by producing some chemicals. These chemicals usually play controlling function in those parts of the body which are far away from their site of synthesis. Transport between these sites and the sites of their action takes place by vascular system in higher plants and circulatory system in higher animals. They are effective in very low concentration.

3.1 CONTROL IN PLANTS

Control through plant hormones:

Plants are the major part of our environment, they are sessile living organisms. Though remain fixed at one place, they respond to a variety of stimuli like animals. Some of their parts having special tissues, which produce special chemicals for control mechanism and also function as coordination chemicals. Plants usually respond to these chemical messages by adjusting their pattern of growth and development. These chemical messages are recognized as **hormones**, a Greek word meaning "to excite". The plant hormones commonly called **phytohormones**, are also known as **growth regulators**.

The concept of chemical messengers in plants emerged from a number of common observations for examples phototropism which shows that when the growing tip of a plant is illuminated from one side it will bend towards light. It was found that this response to light was due to the presence of a hormone in its growing tip. This hormone was named auxin by **F.W. Went**.

Plant hormones control and coordinate the plant responses in two ways:

(i) By showing movement and regulating various metabolic functions.

(ii) By controlling and initiating growth at various regions of plant.

3.1.1 Plant movement:

Movement is one of the property of living organisms. Animals show noticeable movement in the form of locomotion, which is not observed in plants. The movements in higher plants are chiefly in the form of bending, twisting and elongation of certain parts or organs. These movements occur in response to certain stimuli and the direction of response is related to the direction of stimulus. Such responses are called **tropisms** (Tropos means 'turn').

Tropisms are growth responses that result in curvatures of whole plant organs away or towards stimuli. There are three stimuli which can induce tropism i.e. light (Phototropism); gravity (Geotropism) and touch (Thigmotropism). You have already studied different types of plant movement in previous chapter (Chapter 2).

3.1.2 Biological clock and circadian rhythms:

Plants and animals have developed within themselves a wonderful mechanism to measure the passage of time and the means to regulate their physiological and metabolic activities which means that a clock system is present in a living organism. It has long been known that the leaflets of certain plants open during the daytime and close at night but these rhythmic movements have been seen to continue even if the plants are kept in total darkness. It shows that the rhythmic movement of plant was not only controlled by light intensity and temperature changes but was due to an independent time measuring system called **biological clock**.

Living organisms when repeat their biological or behaviourial activities at regular intervals, this behaviour is called **biological rhythms** or **biorhythms**. When these biorhythms occur with a frequency of about 24 hours they are called **circadian rhythm** (L. Circa=about, approximately; dies=day).

Circadian rhythms also take place if organism is taken away from environmental factors e.g. a bean plant will continue its sleep movements even if kept in constant light or constant darkness, the leaves are not simply responding to sunrise or sunset.

Recently such rhythmic movements have been investigated in the growth rates of young oat seedlings, photosynthesis and luminescence in algae and marine dinoflagellates and in the CO_2 metabolism in *Bryophyllum*. These rhythms have seen to be controlled internally by an efficient time measuring system and are independent of light and temperature effects. These types of rhythms are **endogenous**. This is a fact that an independent oscillating (fluctuating) system is present in all individuals and is inherited from one generation to next generation. This system does not alter unless stimulated by a sudden change in the natural environment.

3.1.3 Photoperiodism:

The length of day light period has marked influence on the behaviour of plants particularly on their flowering. The phenomenon in which the influence of day length on plants is studied is called **photoperiodism**. It may also be defined as "response of plants to relative length of the day and night".

3.1.4 Responses to environmental stress:

Changes in environmental conditions are the big threats for living organisms especially for plants. These factors which change the normal conditions of light, CO_2, nutrients, temperature, etc. cause severe stresses on plant. The stress can be defined as an environmental factor that cause adverse effects on growth, reproduction and survival of an organism. Plants either die due to these adverse conditions or cope with these stresses by evolutionary adaptations that enable certain plants to survive in the stressful conditions. The common environmental stresses for plants are:

(i) Water shortage (Drought condition)
(ii) Less oxygen supply
(iii) High concentration of salt in the soil
(iv) High temperature
(v) Low / Cold temperature
(vi) Herbivory / over grazzing

(i) Response to drought condition:

A condition in which water content of soil is very low, a plant may be stressed by shortage of water because plant loses its water by high rate of transpiration. Plants growing in drought condition have control system to cope with this drought stress.

Many plants respond to water deficit, help the plant, to conserve water by reducing rate of transpiration. Water deficit in a leaf causes guard cells to lose turgor, a simple control mechanism that shows transpiration by closing stomata. It also stimulates increased synthesis and release of **abscisic acid** from mesophyll cells in leaf, this hormone helps in keeping stomata closed. Leaves respond to water deficit in several other ways.

Root growth also responds to drought by developing deeper root system to enable their exposure with maximum soil water and inhibiting growth of shallow roots.

(ii) Response to oxygen deficiency:

Some plants are structurally adapted to very wet habitat or marshes. They have developed aerial roots that provide access to oxygen. Another structural adaptation is the development of air tubes that provide oxygen to submerged roots.

(iii) Response to salt stress:

High salt of soil stresses the plant by lowering the water potential of soil due to which exosmosis occurs. The plants especially halophytes have salt glands in their leaves where desalination occurs. As a result salt is pumped out from plants. However, except halophytes, other plants can not survive in salt stress for long.

(iv) Response to heat stress:

High heat in the environment can harm and ultimately kill a plant by denaturing its enzyme and damaging its metabolism. One way to cope with this stress is the transpiration, which produces cooling effect in plants by evaporation. Another way is backup response that enables plant to survive in heat stress. Above 40°C plant cells start synthesizing relatively large quantities of special proteins called **heat-shock-proteins**, which prevent enzymes and metabolic proteins from getting denatured.

(v) Response to cold stress:

When the temperature of environment falls, a change in the fluidity of cell membrane occurs, it loses its fluidity as the lipids become locked into crystalline structures. This alters solute transport. Plants respond to cold stress by altering the lipid composition of membrane.

In freezing condition, changes in solute composition of cells by producing different polymers of fructose (fructans), which allow the cytosol to super cool without ice forming, though ice crystals may form in the cell-walls.

(vi) Responses to herbivory:

Herbivory is the process of eating of plant by herbivorous animals. It is an especial stress for plants being commonly eaten up by animals. Plants overcome excessive herbivory by developing thorns and production of distasteful or toxic compounds.

3.1.5 Defence against pathogens:

Plants are exposed to pathogens like viruses, bacteria and spores of fungi, which can cause different plant diseases. We have already studied some pathogenic plant diseases in class XI biology. Plants normally not get affected by such organisms because they have their own defence system against the pathogens.

Like an animal's skin the epidermal layer of plant serves as first line of defence against pathogens. But some pathogens become successful to enter through wounds or through natural openings like stomata. Once a pathogen invades, the plants use chemicals to attack on pathogen. This chemical attack is the second line of defence. The infected plant produces a variety of compounds called **phytoalexins**, an antibiotic, which destroys or inhibits the growth of micro organisms.

During infection molecules of pathogen and injured plant tissues function as **alarm substances**.

3.2 PLANT HORMONES

Certain chemicals produced by plants have profound effect on their subsequent growth and development. Such chemicals are called plant hormones or phytohormone. They are synthesized by plants in minute concentration and exert their effect either by altering gene expression, activating or inhibiting enzymes or changing properties of membrane. They are produced in young

embryonic tissues as there is no specific organ for their production in plants.

There are five kinds of plant hormones. These are:

(i) Auxins (ii) Gibberellins (iii) Cytokinins
(iv) Abscisic acid (v) Ethene

1. Auxins (Gr. Auxano= To increase):

Auxins are a class of plant growth substances both natural and synthetic first revealed by Fritz-Went (1926).

They were the first of the major plant hormones to be discovered and are a major plant-hormones to be discovered and are a major co-ordinating signal in plant development. Indole-acetic acid (IAA) is the principle type of auxin of higher plants, synthesized at the apices of stem and root (apical meristem)

In addition to (IAA) other naturally occurring auxins are : 4-chloro-indole acetic acid, phenyl acetic acid (PAA) and indole-3 butyric acid (IBA) where is synthetic auxins include nephtaline acetic acid (NAA), 2,4-dichcloro- phenoxy acetic acid (2, 4-D) and others.

Auxins co-ordinate development at all levels in plants, from the cellular level to organs and ultimately the whole plant.

Role of Auxin

(A) Cell division and cell- enlargement:

It stimulates cell division, cell enlargment and brings about increase in length of plant. It stimulates wall loosening factor, for example, elastin to loosen the cell-walls. If Gibberellins are also present, the effect is stronger. It also stimulates cell-division if cytokinins are present.

Xylem tissues can be generated when the auxin concentration is equal to the cytokinins.

(b) Initiation of roots: Auxin also initiates development of adventitious roots when applied at the cut base of stem.

(c) Abscission: In mature leaves and fruits when auxin production diminishes, a layer of thin walled cells is formed at the base of petiole and stalk of fruit. This layer is called abscissic layer and causes fall of leaves and fruit with slight jerk.

(D) Growth of fruit: Auxins produced in young embryo promotes the growth of fruit.

(e) Parthenocarpy: Use of auxin also helps in producing parthenocarpic or seedless fruits.

(f) Apical dominance: Besides growth promoting function, auxin also has inhibitory effect on growth. Growth of apical bud inhibits growth of lateral buds beneath the stem. This phenomenon is termed as apical dominance. Removal of apical bud initiates growth of lateral buds with more leaves and axillary buds.

(g) Weedicide: Auxins are selective weed killer. 2-4-dichlorophenoxy acetic acid (2-4-D) is used to kill weeds in lawns and cereal crops.

Flowering:

Auxin plays a minor role in the initiation of flowering. It can delay the senescence of flowers in low concentrations.

2. Gibberellins:

It is a group of chemicals that promote cell division and cell elongation. First noticed in *Gibberella fujikuroi* fungus which infected rice seedlings and produced a disease called **bakanae** (Foolish seedling). The infected seedlings elongated and ultimately fell over without producing grains. Even extract from the fungus when applied to rice seedlings produced the same disease indicating that a definite chemical compound is responsible for disease. **T.Yabuta** and **T. Hayashi** succeeded in isolating the active substance from the fungus and was named Gibberellin, after the name of genus. Its ability to induce growth attracted the scientists who have isolated 70 different types of Gibberellin many of them occur naturally in higher plants. Major sites of their production are roots, stems and leaves.

Role of Gibberellin:

Gibberellin produces wide variety of effects. One of their effect, like auxin is to stimulate cell division and cell elongation and prevent genetical and physiological dwarfism. For instance dwarf pea plant used by Mendel in his experiment when treated with gibberellin attained normal size. They also mobilize food stored in endosperm by producing enzyme (amylase) that converts starch into sugar which is made available to developing embryo.

They also stimulate flowering, fruit development, bud sprouting, growth of pollen tube and parthenocarpy.

3. Cytokinins:

These are a group of substances both natural and synthetic, which react with auxin to induce cell division. Originally obtained from coconut milk, the other source are Herring sperm DNA and Yeast extract. One of the naturally occurring cytokinin is **zeatin**, which was obtained in pure crystalline form from immature corn grains. **Kinetin,** a synthetic cytokinin has the same effect as that of zeatin.

Role of Cytokinin:

They initiate rapid cell division but only in presence of auxin. They also cause delayed senescence (old age). Detached leaves which would normally lose chlorophyll are prevented from becoming decolourized by their application. They also break seed dormancy and promote fruit development in some species.

4. Abscisic acid:

In contrast to growth promoting hormones like auxins, gibberellins and cytokinins, abscisic acid (ABA) is growth inhibitor produced by plant during adverse environmental conditions such as drought condition and at the onset of winter. It induces dormancy in buds and seeds, causes stomata to close, turns leaf primordia into scale which protects the buds and promotes senescence.

5. Ethene:

The most important role of ethene (a gas), is that it triggers ripening of fruit. It affects permeability of cell membrane, which allows enzymes responsible for destroying chloroplast with the result that red and yellow colours are unmasked and fruit assumes ripened colour. It contributes to leaf abscission and also breaks dormancy of buds and seeds in some species. It also initiates flowering in some plants e.g. pineapple.

3.3 CO-ORDINATION AND CONTROL IN ANIMALS

In higher animals, coordination of cells within the body as well as of the whole body with its environment is achieved by nervous coordination and hormonal coordination, which are the activities of nervous system and endocrine systems, respectively. These two coordination systems connect the sensory and effector systems together to produce effective behavior and homeostasis.

Nervous coordination:

The nervous coordination is brought about by means of nervous system. It is the quickest way of communication within the body of an animal. In this method, communication takes place by electro-chemical messages called **nerve impulse**. The nervous system consists of two types of tissues called **neurons** and **neuroglia** (glial cells).

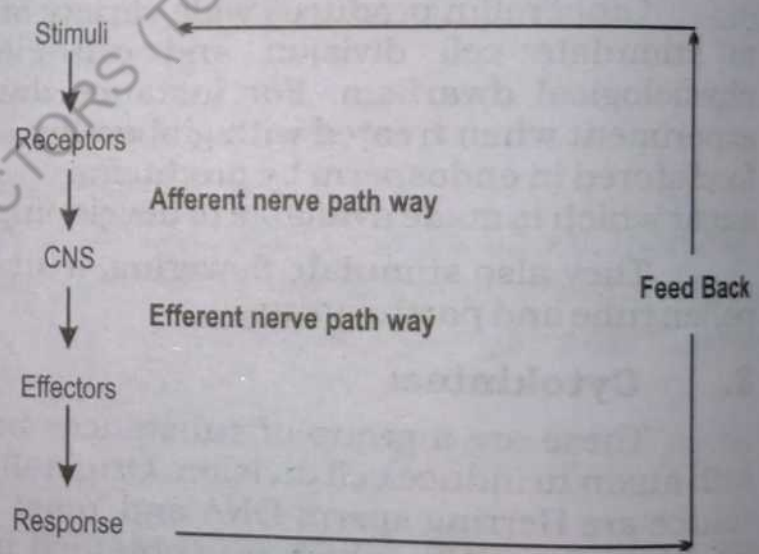


Fig : 3.1 Coordination by mammalian nervous system

Neurons receive informations about any change (stimulus) in external or internal environment of the body through sensory cells or organs called **receptors** and mostly report it to the control centre of the nervous system. After analysis and integration with other stimuli, the control centre sends commands for an appropriate response to the **effector** organs (muscles, glands). Information from the receptors to the control centre are taken by the **afferent nerve pathway** while back from the control centre to the effector by another pathway called **efferent nerve pathway**. The entire communication from the stimulus to the response can occur within milliseconds. The coordination by nervous system is summarized in the figure 3.1.

3.3.1 Nervous Tissue:

1. Neuron :

A neuron is a special kind of animal cell, which can generate and conduct electric current. In order to understand the way of generating electric signals, let us study its structure first.

Structure:

Neurons differ considerably in size and shape but generally differentiated into following three regions: soma, dendrites and axon.

The **soma** is also called as cell body. It contains cytoplasm and nucleus. In addition to typical cell organelles, it contains **Nissl substance**, which consists of ribosomes.

From the soma arises a number of thread like processes, the **dendrites**, which receive stimuli and convey it to the soma.

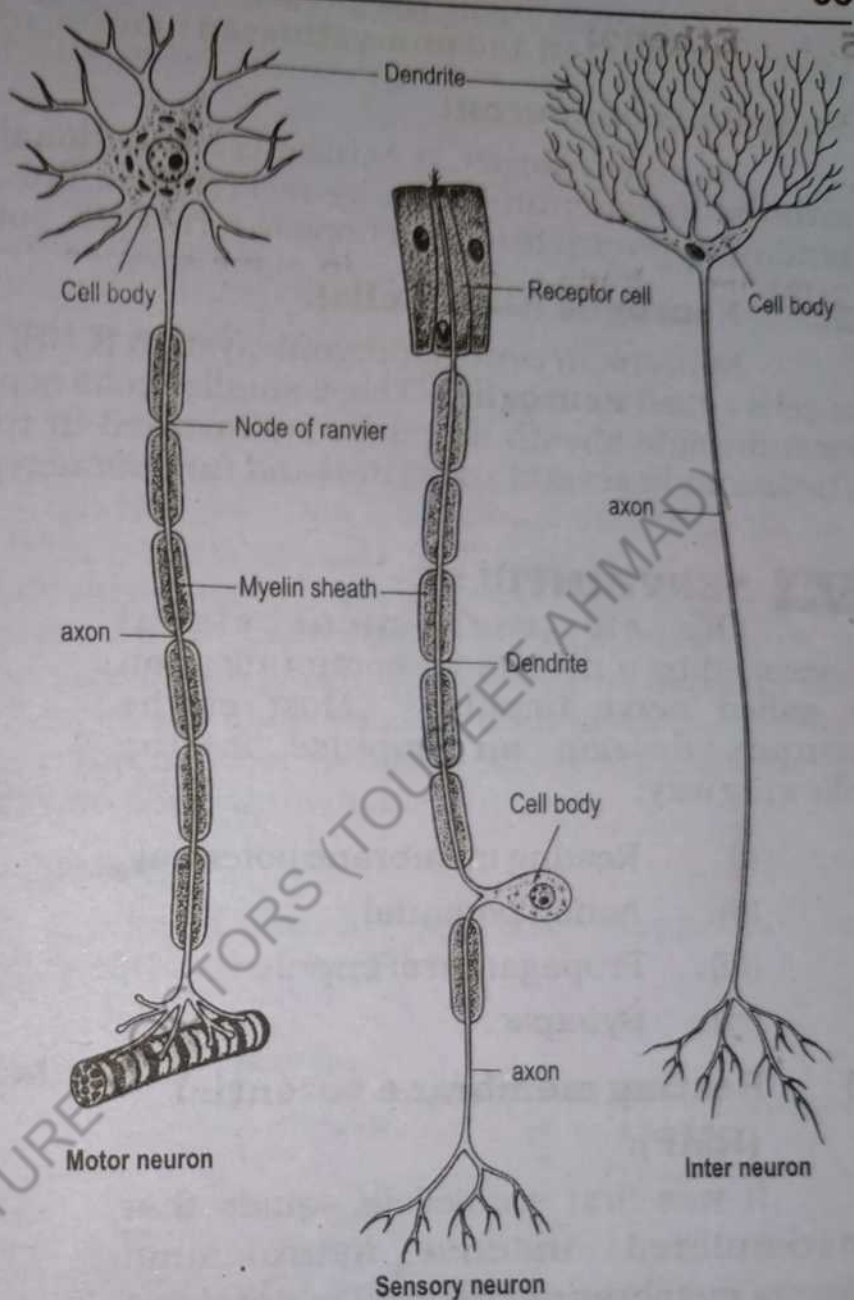


Fig: 3.2 Neuron anatomy

Axon is a long cytoplasmic process which usually arises opposite to dendrites. It is the conducting end of a neuron. It ends in knob like structures, the axon terminals. It originates from a pyramid like area of soma called axon- hillock. The axons of some neurons are covered by a myelin sheath.

Types of Neuron:

Functionally neurons can be differentiated into following three types.

(i) Sensory neuron: It carries sensory information from the receptor to the other neurons or directly to CNS.

(ii) Motor neuron: It takes commands of the control centre to the effector.

(iii) Inter neuron: They are found in central nervous system.

Depending upon the presence or absence of myelin sheath, neurons are called **myelinated** and **unmyelinated** neuron, respectively.

Functions of neuron:

As stated earlier, a neuron is a functional unit of the nervous system, it is involved in communication by receiving stimuli, integrating various stimuli and sending appropriate instructions to form CNS some of the effector organs.

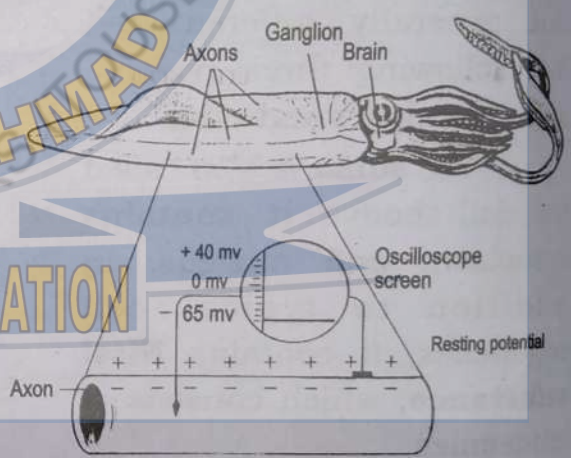
2. Neuroglia (Glial Cells):

Neurons in central nervous system (CNS) are associated with another type of cells called **neuroglia**. These smaller cells separate neurons from one another, form myeline sheath and are also involved in trophic and phagocytic functions. They occur in several structural and functional types.

3.4 NERVE IMPULSE

The electrochemical signal developed by a neuron for communication is called nerve impulse. Most of the neurons develop an impulse in the following way:

(i) Resting membrane potential
(ii) Action potential
(iii) Propagation of impulse
(Iv) Synapse.



(i) Resting membrane potential (RMP):

It was first studied in squids that unstimulated, inactive neurolemma (Plasma membrane of neuron) maintains a charge of -65mv (variable between -40mv to -90mv). This electrical potential is called **resting membrane potential**. This polarity is due to the unequal distribution of ions across the neurolemma. It was found that there is a greater concentration of sodium ions outside than inside the membrane.Similarly, potassium ions are concentrated much inside than outside the membrane. This is attributed to the activity of ATP driven sodium-potassium pump in the neurolemma. Towards the inner surface of the membrane, negative

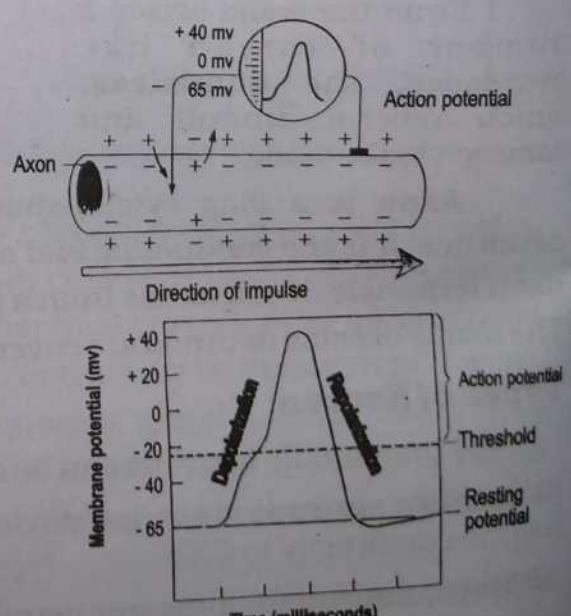


Fig: 3.3 The original nerve impulse studies on giant squid

organic ions such as proteins, organic acids, etc are more concentrated, which make the polarity of the neurolemma negative.

(ii) Action potential:

It is a temporary localized reversal of the polarity of the neurolemma, which occurs when neurolemma is stimulated (e.g. electric shock, touch, sound, vibrations etc). During the action potential, the polarity of neurolemma first changes to +40mv (i.e. depolarization) and then restores to -65mv again (i.e. repolarization). This action potential is extremly rapid as it occurs only in a few milliseconds. to happen.

The change in potential across the membrane is due to the presence of sodium and potassium channels in the neurolemma. Upon stimulation, the sodium channels open to allow the rushing in of Na+ ions inside the cell, so the membrane potential changes from negative to zero and then proceeds upto +40 mv. At this stage, the sodium channels (gates) are automatically shut down but simultaneous potassium channels open to allow their outward movement. As a consequence, the +vely charged membrane gradually restores its negative charge of -65 mv. Since the sodium ions accumulate inside and potassium out side, at this stage, the sodium potassium pump becomes operational to restore the initial accumulation of sodium outside and potassium inside.

(iii) Propagation of the impulse:

The action potential developed locally spreads along the entire neurolemma, is called propagation of the nerve impulse.

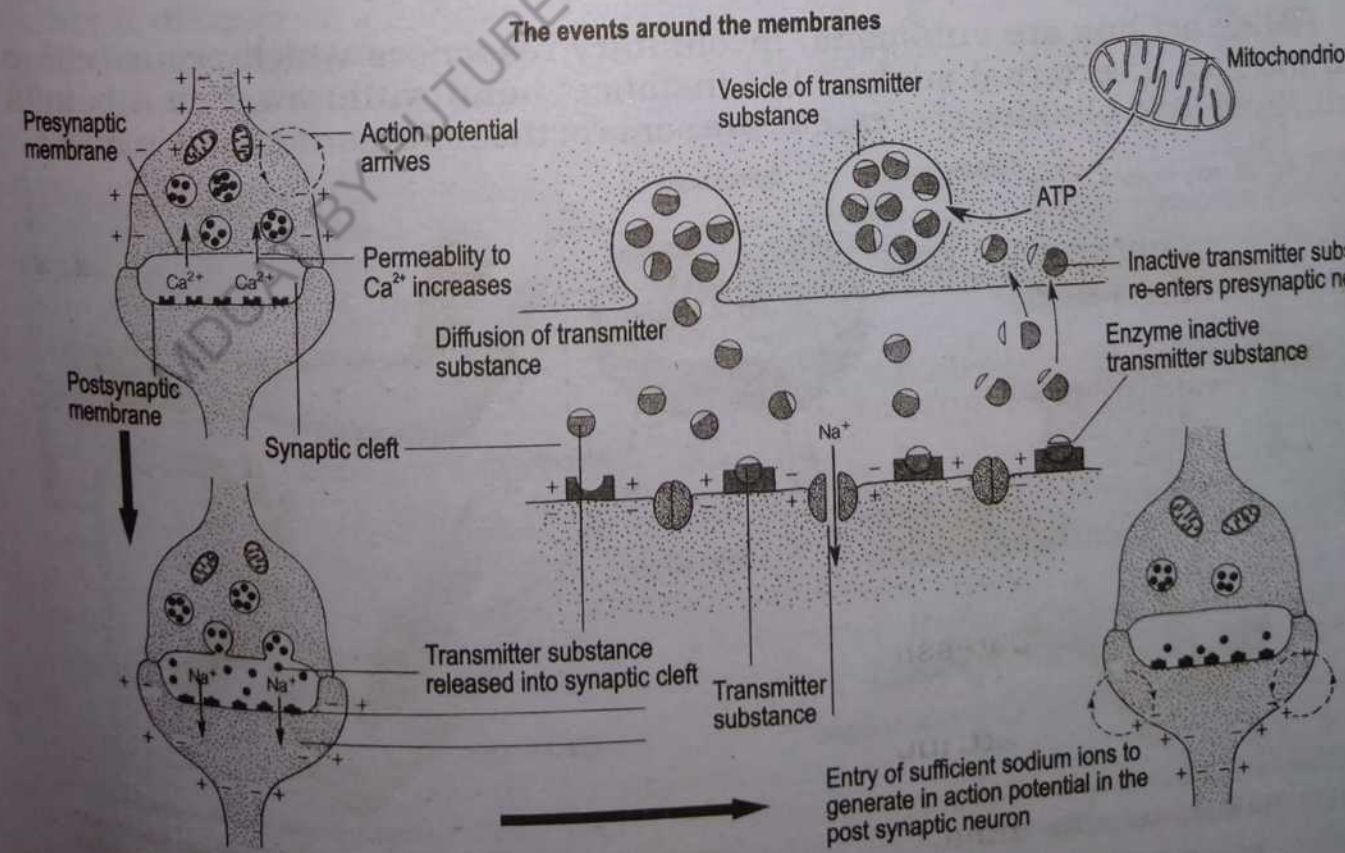


Fig: 3.4 Chemical transmission at the synapse

(iv) Synapse:

The region where the impulse moves from one neuron to another is called a **synapse**. It consists of three components; a pre-synaptic membrane (the axon terminals), a narrow space called synaptic cleft and a post synaptic membrane (the dendrite of other neuron). However, the post-synaptic membrane may be a muscle cell membrane. In that case, the synapse is termed as **motor end plate**(fig: 3.4).

It is only the axon terminal where impulse is transmitted from pre synaptic to post synaptic cell because it contains vesicles containing a chemical, the **neurotransmitter**, which is involved in the transmission of the impulse. As a consequence of the propagation of impulse down to axon terminals, the calcium channels, present there, are opened allowing the diffusion of calcium ions from the synaptic cleft to inside the axon terminals. This causes the vesicles containing neurotransmitter to fuse with the axon terminals and release the neurotransmitter into the synaptic cleft. The neurotransmitters bind to the receptors on the post-synaptic membrane, which generate action potential in the post-synaptic cell. The neurotransmitters are then reabsorbed by the pre-synaptic cells for reuse.

Various neurotransmitters such as acetylcholine, norepinephrine (noradrenaline), glycine, gaba, serotonin, dopamine etc. have been identified.

> Events occurring at the neuromuscular synapse are considered as chemically very important since blocking transmission at this site with commonly used drugs, one can promote muscle relaxation during anesthesia, and reduction of muscle spasticity in certain neurological conditions.

3.4.1 Reflex action:

Reflex actions are automatic, involuntary responses which occur either due to internal or external stimuli. For instance, hand withdrawal on a painful stimuli, knee-jerk, blinking of eyes, etc. are some of the reflexes common in man.

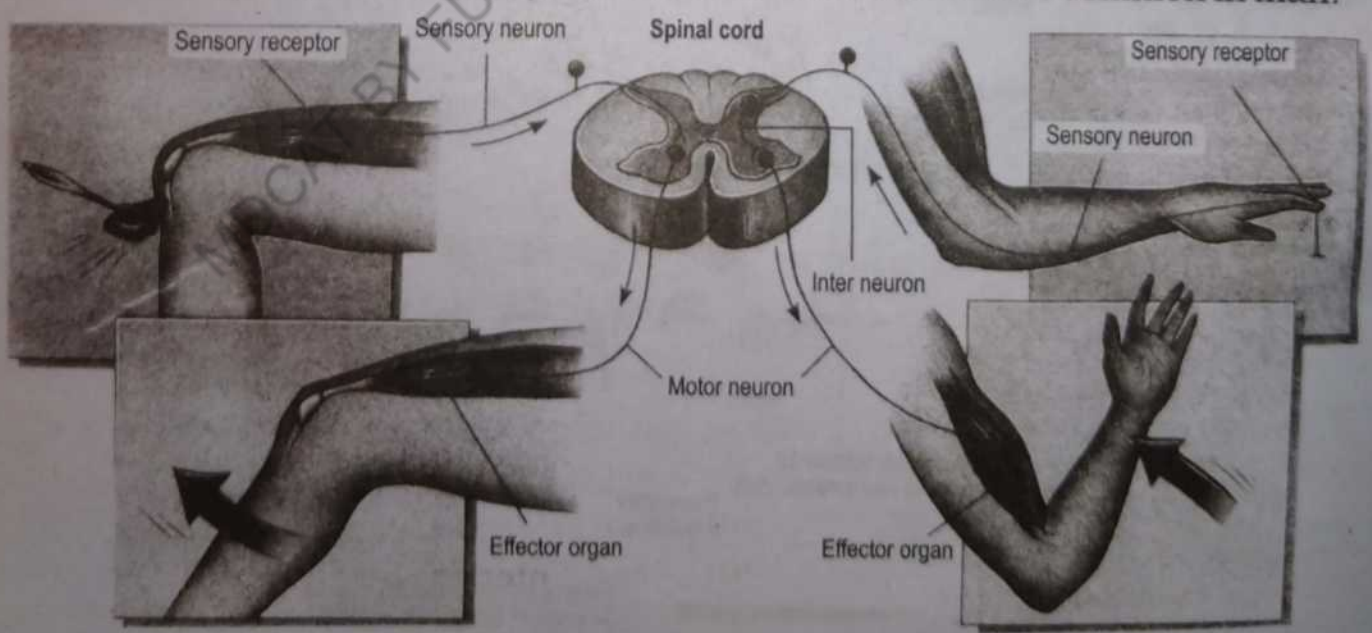


Fig: 3.5 The spinal cord and spinal reflexes

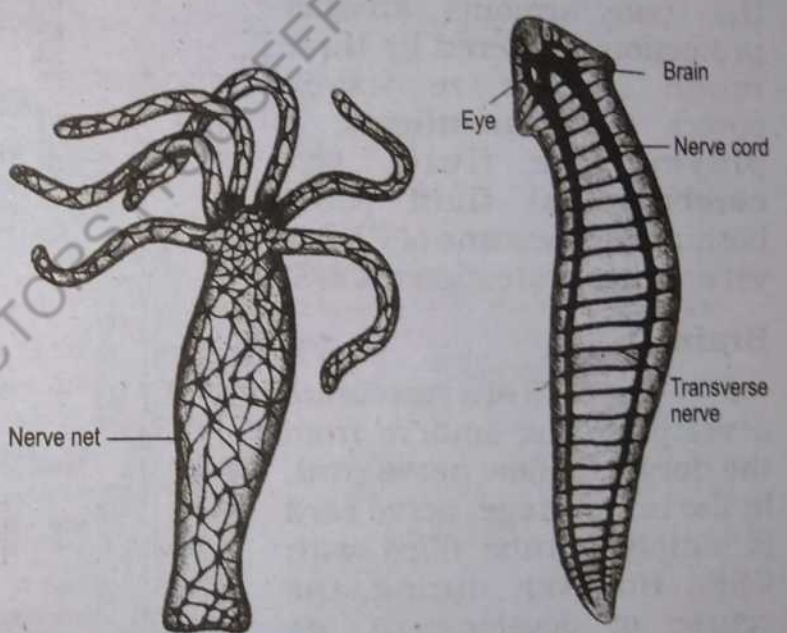
A reflex involves usually two neuron, a sensory and a motor neuron. The pathway of such transmission is called **reflex arc**. In this case, since only one synapse is involved, so such reflex is called **mono-synaptic**. Knee-jerk is an example of mono-synaptic reflex. However, in ve rtebrates most of the reflexes are polysynaptic as they involve one or more interneurons imposed in between sensory and motor neurons. Due to interneuronal synapse, the stimulus can also be sent to the brain, which enables these animals to influence some voluntary control on the reflexes.

3.5 EVOLUTION OF NERVOUS SYSTEM

In different groups of animals, two types of nervous systems can be recognized, one is diffused nervous system and the other is centralized nervous system. It is correlated with the life style of animals.

1. Diffused Nervous System:

This is found in Cnidarians and Echinoderms. In *Hydra* and other cnidarians, because of the radial symmetry, there is no anterior or posterior ends. The nervous system consists of a net work, the nervenet of neurons, which is woven through the tissues of the body. The flow of information through this nervenet is not highly directional, rather it diffuses in all directions from the point of stimulation. In this kind of nervenet, the transmission of impulse is slow possibly because of the synapses involved. Thus, initially the response is localized. If the stimulus is strong and persistent such as capturing the prey, then the whole body involves.



Hydra, a cnidarian, has a nerve net with no centralization

Planarian, a flatworm, has a small brain or an anterior ganglion, i.e. part of two longitudinal nerve cords

Fig: 3.6 Invertebrate nervous systems

2. Centralized nervous system:

It is the characteristic of bilaterally symmetrical animals, which have a definite anterior and posterior ends. Since the head is the first part of the body that encounters the food, dangers, etc so they require sensory organ and a control centre of the nervous system where the sensory information from different sensory organs are brought for integration and to develop a coordinated response of the body.

Flatworms, such as *Planaria* are among the simplest animals having a centralized nervous system. It consists of an anterior brain (a concentration of neurons), which is connected with the sensory organs. From the brain of *Planaria*, arise two cord like nerves running longitudinally through the body. The two nerve

Cords are connected with each other at several points along the entire length of the body through transverse nerves, which coordinate the movement of the two lateral sides of the body.

3.6 HUMAN NERVOUS SYSTEM

Like other vertebrates, the human nervous system is of centralized type. It can be divided into following different components that differ in function as summarized in figure 3.7.

3.6.1 Central Nervous System (CNS):

The CNS consists of a brain and a spinal cord (hollow nerve cord). Both consists of upto 100 billion inter neurons. Both brain and spinal cord are protected in bony armour, the skull and the canal of the vertebral column, respectively. Inside the bony armours, another protection is offered by three tough connective tissue covers called **meninges**. A plasma-like fluid, the **cerebrospinal fluid** (CSF) bathing the neurons of CNS is yet another protection to CNS.

Brain:

The CNS of a vertebrate develops in the embryo from the dorsal, hollow nerve cord. In the initial stage, nerve cord is simply a tube filled with CSF. However during the course of development, its anterior part enlarges to form the primary brain vesicle. As the development proceeds, the primary brain vesicle sub-divides into three irregular vesicles, the **fore-brain**, **mid-brain** and **hind-brain**. Later, different parts of mature brain develop from these vesicles by selective thickening and folding processes in the walls and roof of the brain. Meanwhile the central canal becomes four fluid filled cavities called **ventricles**.

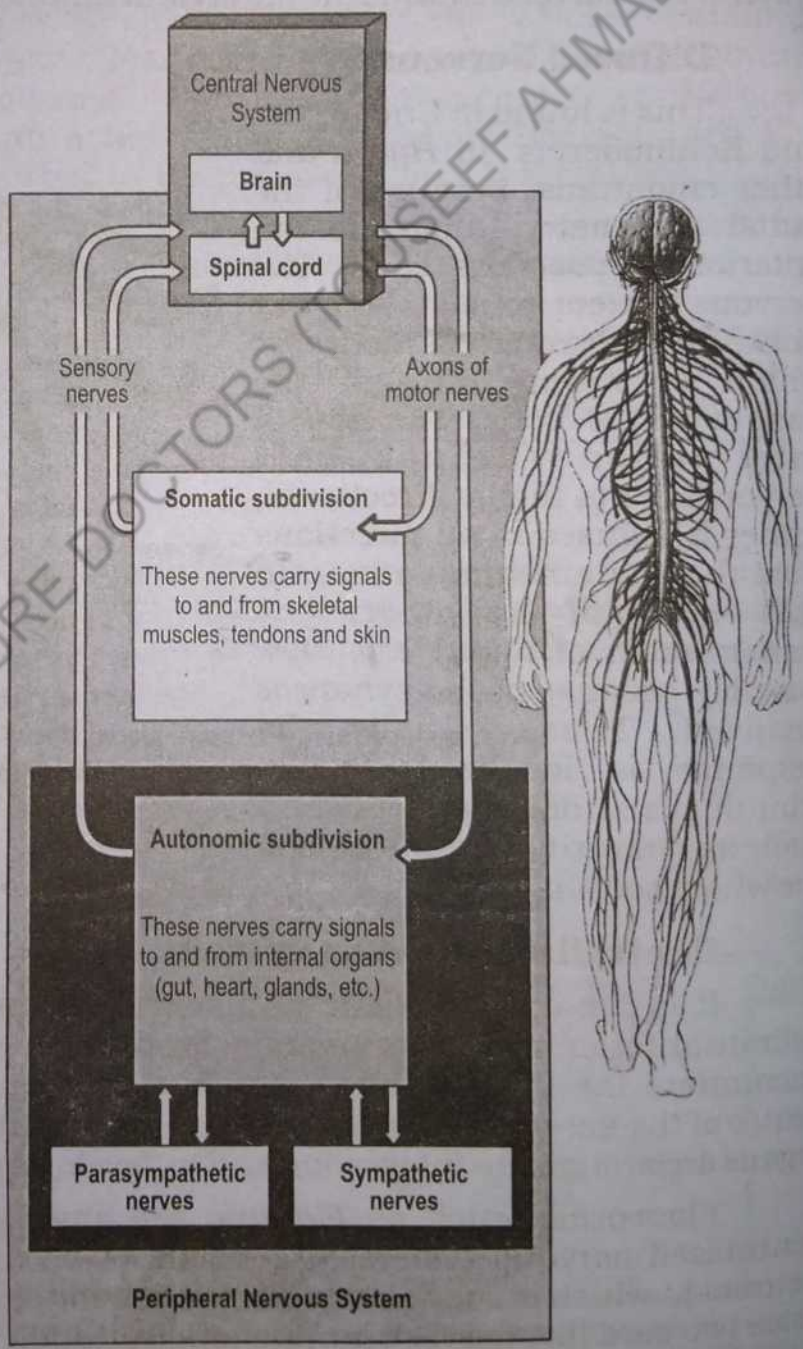


Fig: 3.7 Functional divisions of the nervous system

Fore-brain:

Fore-brain can be divided into two regions, the **telencephalon** and the **diencephalon.**

The telencephalon is the largest part of fore-brain. It is differentiated into two **cerebral hemispheres** or **cerebrum**. Each hemisphere consists of an outer grey matter or cerebral cortex and an inner white matter. Cerebral cortex is the largest and the most complex part of human brain. It is highly convoluted to occupy greater number of inter neurons. Cortex is the seat of all conscious activities. It coordinates different senses together. It is the place which is involved in intelligence, reasoning, memory etc. Functionally, it can be differentiated into an anterior frontal lobe, a lower central temporal lobe, a parietal lobe and a dorsal occipital lobe. The activity of the two cerebral hemispheres is coordinated by **corpus callosum**.

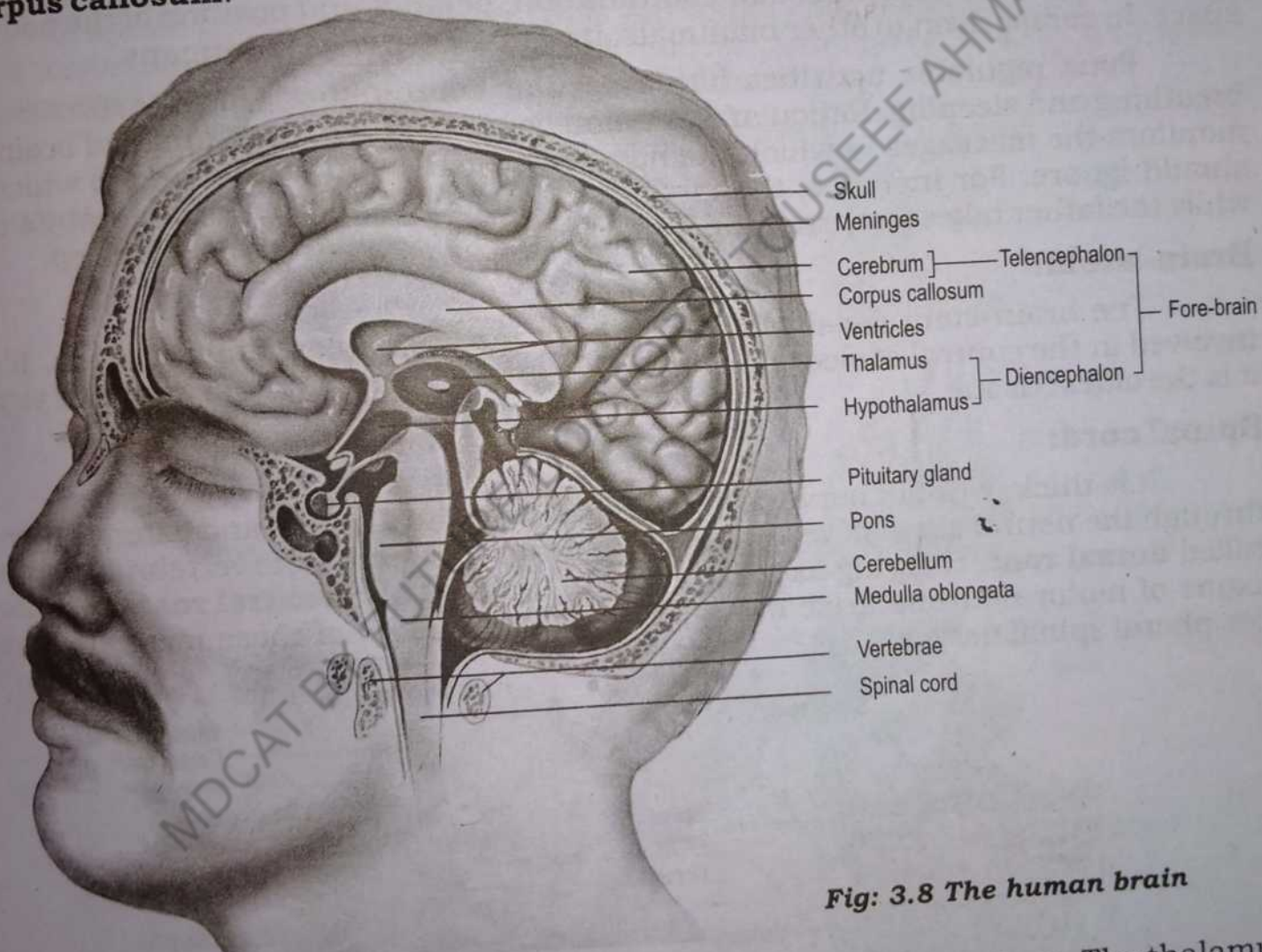


Fig: 3.8 The human brain

The diencephalon consists of **thalamus** and **limbic system**. The thalamus is a **clearing house** for sensory impulses as it receives them from different parts of brain and relays them to the appropriate part of the motor cortex. It is also involved in the perception of pleasure and pain.

The limbic system consists of hypothalamus, amygdala, hippocampus and some parts of thalamus. The hypothalamus is important in regulation of homeostasis. It regulates pituitary gland. It is also involved in regulation of body

temperature, blood pressure, hunger, thirst, aggression, pleasure and pain. The amygdala produces sensation of pleasure, punishment or sexual arousal upon stimulation. The hippocampus is involved in long term memory.

Mid-brain:

In mammals, particularly in man, mid-brain is relatively very small. It receives and integrates sensory information like vision, odour as well as sensory information from the spinal cord and relays them to fore-brain.

Hind- brain:

The hind brain consists of medulla oblongata, cerebellum, pons and reticular formation.Medulla oblongata has reflex centers for vital tasks like breathing, heart beat, blood pressure, coughing, swallowing , hiccuping, sneezing, vomiting , digestion etc. Cerebellum like cerebrum is highly convoluted. It is involved in precision in muscular coordination, balance and position of the body in space. In comparison to other mammals, it is greatest in size in humans.

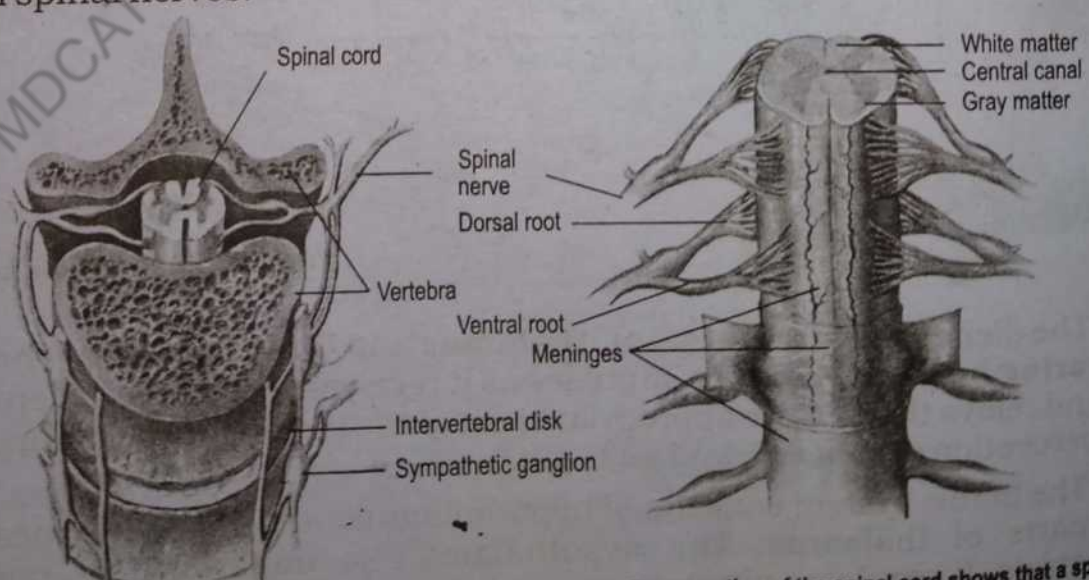
Pons regulates activities like muscular coordination, facial expressions, breathing and sleeping. Reticular formation lies in medulla, pons and mid brain. It monitors the messages to which the nervous system should react and to which it should ignore. For instance, the mother will instantly awaken to her baby's cry while the father takes it as irrelevant stimulus so ignores and enjoys his sleep.

Brain- stem:

The brain-stem consists of mid-brain, medulla oblongata and pons. It is involved in the control of sleep and wakening. From the evolutionary point of view, it is the oldest tissue.

Spinal cord:

It is thick, whitish nerve cord that lies below the medulla and extends down through the neural canal of vertebrae upto the hips. Between the vertebrae, nerves called **dorsal root**, carrying axons of sensory neurons and **ventral roots** carrying axons of motor neurons arise from the spinal cord. Both of these merge to form peripheral spinal nerves.



Cross section of showing spinal nerves

Fig: 3.9
The anatomy of the spinal cord

Cross section of the spinal cord shows that a spinal nerve has a dorsal and ventral root

In cross section, the spinal cord is differentiated into two areas, an outer white called **white matter** and an inner gray, called **gray matter**. The outer region consists of neurons while the inner consists of nerve fibers of gray matter. Messages are brought by sensory neurons through dorsal root. Their somas in each spinal nerve, are located in one of the swellings, the **dorsal root ganglia** located near but back of the spinal cord. The first synapse of each sensory neuron is located in the grey matter of the spinal cord and their axons extend through the ventral root to the spinal nerves and then to the appropriate effector cells.

Spinal cord serves as an express way for signals between autonomic nervous system and brain. It is also the control centre for many reflexes.

3.6.2 Peripheral Nervous System (PNS):

In man, the 12 pairs of cranial nerves, which arise from the brain and 31 pairs of spinal nerves, which arise from the spinal cord constitute the PNS. The PNS transmits signals between CNS and the rest of the body. Cranial and spinal nerves are further classified according to their function.

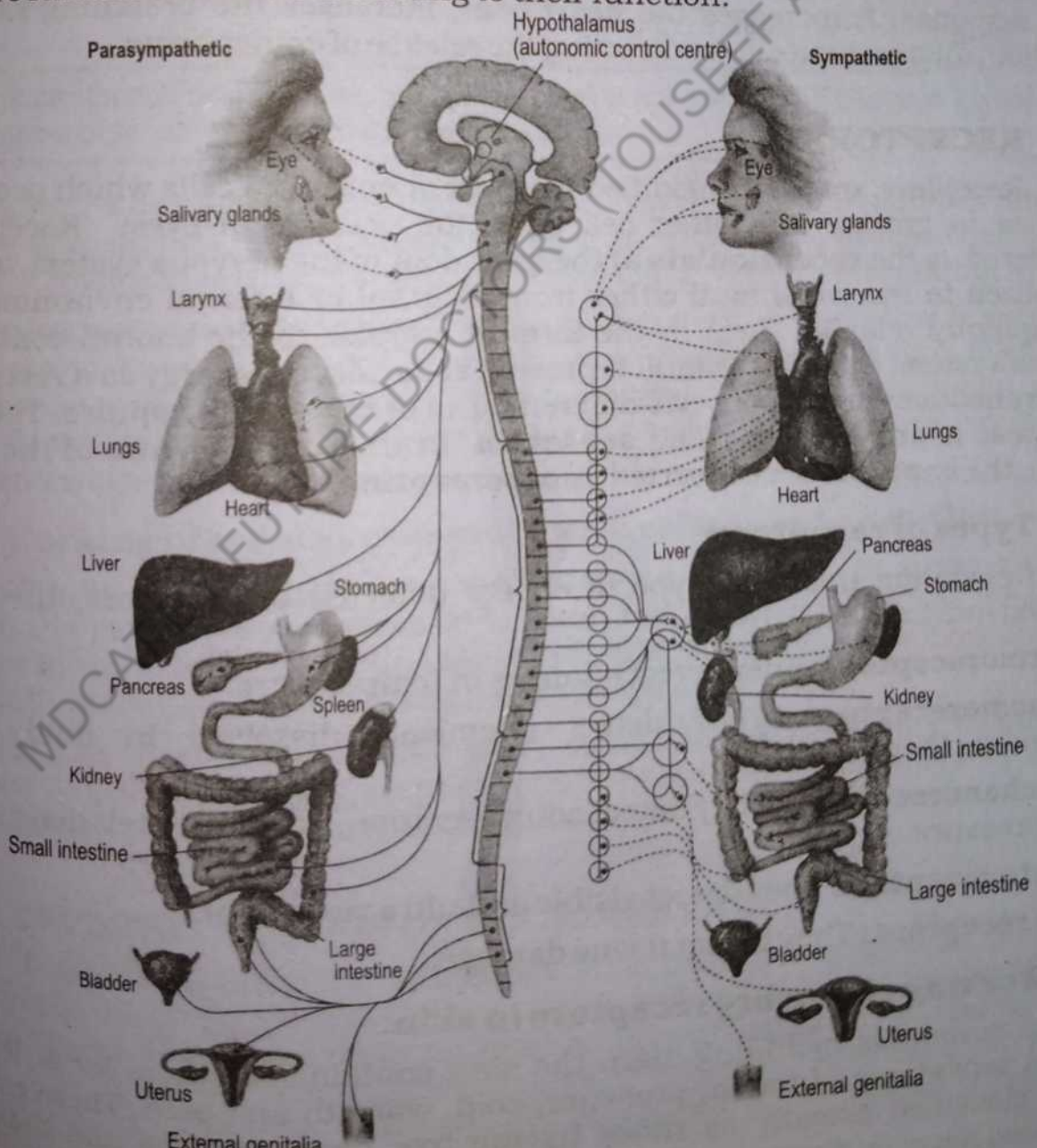


Fig: 3.10 The autonomic nervous system

The nerves that are related to the skeletal muscles (voluntary activity) constitute the **somatic nervous system** while the others that deal with smooth muscle (involuntary activity), heart and glands constitute the **autonomic nervous system** (Fig 3.10). They deal with the internal organs of the body.

Autonomic nervous system: It is further divided into parasympathetic and sympathetic nervous systems.

Parasympathetic nervous system: It is formed by some of the cranial nerves, vagus nerves and the spinal nerves arising from the sacral vertebrae. It promotes all the internal responses we associate with a relaxed state, for instance contraction of pupil of eye, digestion of food, slow heart beat, etc.

Sympathetic nervous system: It also affects the visceral organs but its nerves arise from the thoracic and lumber regions of spinal nerves. It produces the opposite effect on the visceral organs in comparison to the parasympathetic nervous system. It prepares the body for highly energetic activity such as fight or flight response. It increases the heart beat, increases the breathing rate, slows digestion, dilates pupil etc. by directing the release of epinephrine.

3.7 RECEPTORS

Receptors are either modified neurons or epithelial cells which occur either singly or in groups with other cell types for example in eyes. Receptors are considered as the **receptionists** at the front door of the nervous system, which are specialized to receive stimuli either from external or internal environments and subsequently relaying them in the form of impulse to the control centre of the nervous system. Since all stimuli represent some form of energy so a receptor acts like a transducer which converts different form of energy into impulse. The stage of awareness of stimulus is called **sensation**. In the control centre of the nervous system, the impulses are converted into **perception**.

3.7.1 Types of receptors:

Depending upon the type of energy detected by receptors, they can be classified into following groups.

(i) Thermoreceptors : They detect changes in temperature.

(ii) Chemoreceptors: They detect chemicals dissolved in fluid medium surrounding them.

(iii) Mechanoreceptors: They detect sound, motion, position in relation to gravity, touch, pressure.

(iv) Photo receptors: They detect visible and ultra violet light.

(v) Pain receptors : They detect tissue damage.

3.7.2 Working of sensory receptors in skin:

In mammals including man, the skin contains receptors for at least five different sensations of touch, pressure, cold, warmth and pain. These receptors can be classified broadly as those having free nerve endings and those with capsulated nerve endings.

(i) Free nerve endings:

They are the simplest type, which lie in epidermis or dermis. They are of different types and involved in touch, pressure (mechanoreceptors), pain (nociceptors) and heat and cold (thermoreceptor). All of these receptors adapt very slowly to stimulation.

(ii) Encapsulated receptors:

The nerve endings of these receptors are enclosed in capsule of connective tissues. Following capsulated receptors lie in the skin.

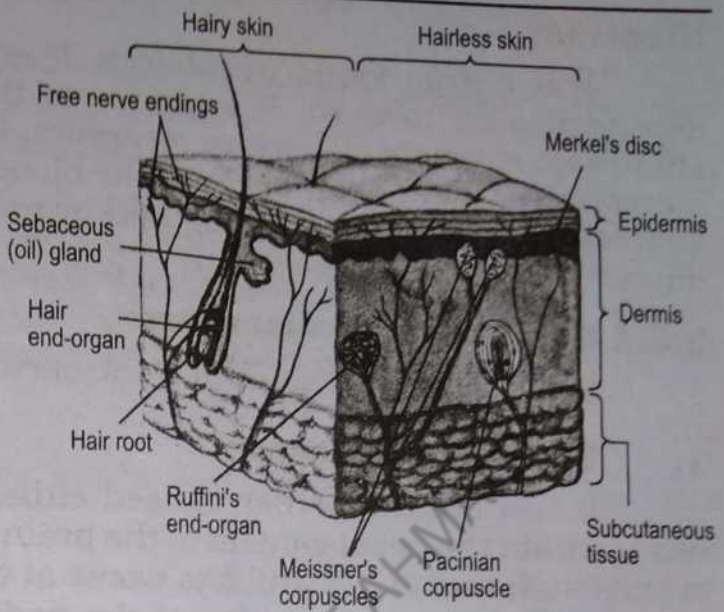


Fig: 3.11 Body surface receptors

The distribution of various receptors in the skin is not uniform. Regions with greatest number of sensory receptors are finger tips and tongue.

a) Meissner's corpuscle: Abundant in hair-less areas of skin such as finger tips, lips, eye-lids, nipples, palms, soles etc, these are sensitive to touch. Their capsules consist of thick collagen fibers with spiral and highly coiled nerve ending .

b) Pacinian corpuscle: In this corpuscle, the sensory nerve ending is surrounded in concentric, onion-like layers of membranes alternating with fluid filled spaces. These are located in dermis as well as in some internal organs and freely moveable joints. Pacinian corpuscles respond to rapid change in pressure associated with touch and vibrations.

3.7.3 Working of sensory receptors with reference to arteries:

Carotid arteries and aortic arch are very important in a sense that both contain the most sensory mechanoreceptor and the baroreceptors, which detect changes in the arterial mean pressure and pulse pressure and report any change to medulla oblongata for proper regulation of blood pressure.

The aortic arch and carotid sinus contain another sensory receptor called aortic body and carotid body, respectively. Both of these are chemoreceptors which are sensitive to CO_2 and H^+ in the blood.

3.8 EFFECTS OF DRUGS ON COORDINATION

A drug is a chemical substance that provokes a specific physiological response in the body. Some drugs are useful medically to treat emotional stress or certain illness. Others act on brain producing artificial pleasure feeling. Different drugs have different effects. They act as stimulants, depressants, hypnotics, analgesics, hallucinogens, psychedelics, etc. However, we shall discuss here the nicotine only.

Nicotine:

It is a drug found in tobacco. It acts as stimulant and is responsible for dependence on tobacco. It suppresses the action of acetylcholine and directly stimulates a variety of sensory receptors. However, in habitual smokers, the drug increases the heart beat, narrows the blood vessels (raises the blood pressure) and stimulates the nervous system, thereby reducing fatigue, increasing alertness and improving the concentration.

3.8.1 Some nervous disorders:

Some common disorders of the nervous system are as follows:

1. Parkinson's disease:

It is a brain disorder caused either by degeneration or damage to nerve tissue within the basal ganglia of the brain. The disease begins as a slight tremour of one hand, arm or leg which is worse at the time when limb is in rest. Later, the disease affects both the sides of the body and causes stiffness, weakness and trembling of the muscles. The intellect remains unaffected until late in the disease, although speech may become slow and hesitant. **Leodopa**, which the body converts into **dopamine** is usually the most effective drug. It is helpful in minimizing the symptoms but cannot halt the degeneration of neurons of brain.

2. Alzheimer's disease:

It is a progressive degeneration of neurons of brain (especially cerebral cortex and hippocampus). It causes dementia (loss of memory). The disease progresses in three broad stages. At first, the patient notices his forget fulness. In the second phase, there is a severe loss of memory particularly for recent events. The victim also becomes disoriented as to time or space, losing his way even on familiar streets. Anxiety increases with sudden changes in mood. In the third stage, the patient becomes severely disoriented and may suffer from symptoms of psychosis such as hallucinations (hearing voices or seeing faces when no one is there) and paranoid delusions (A fixed, irrational idea not shared by others and not responding to reasoned arguments).

3. Epilepsy:

Epilepsy is a tendency of recurrent seizures or temporary alteration in one or more functions. The seizures are transient neurological abnormalities caused by abnormal electrical activity in the brain. The seizures may be spontaneous or due to some stimulus such as flashing light. The seizures may be generalized or partial . The generalized seizure is characterized by complete unconsciousness, stiff body with twitches or jerks. In partial seizure, there is a momentary loss of consciousness without abnormal movements. Anticonvulsant drugs are administered.

3.9 CHEMICAL COORDINATION

Chemical coordination between different cells or organs within the body of multicellular animals is more primitive than nervous coordinat ion. In this kind of

coordination a group of cells releases specific chemicals, which regulate the activities of other cells of the body.

In the body of vertebrates, various types of signaling chemicals such as neurotransmitters, pheromones, hormones are recognized. However, in the proceeding discussion we shall consider hormones only.

Hormone is a secretory product of **endocrine glands** which are special group of cells or organs. Hormones are released directly in the blood stream to be carried it to other parts of the body, where they affect particular target cells. A minute quantity of hormone may have a profound effect on an organism's activities like behaviour, development, growth, reproduction, etc.

3.9.1 Chemical nature:

Hormones are organic molecules which can be divided chemically into following types:

i) Peptide hormones: They occur as short chain of amino acids (e.g: ADH, Oxytocin, etc) or as long chain of amino acids (e.g. Glucagon insulin, Prolactin, etc). The former are called **peptide hormones** while the later are called **protein hormones.**

ii) Modified amino acids hormones: Few hormones consists of modified amino acids e.g. Thyroxine, Epinephrine, Norepinephrine.

iii) Steroid hormones: These are lipid in nature. Examples are estrogen, progesterone, testosterone, aldosterone, etc.

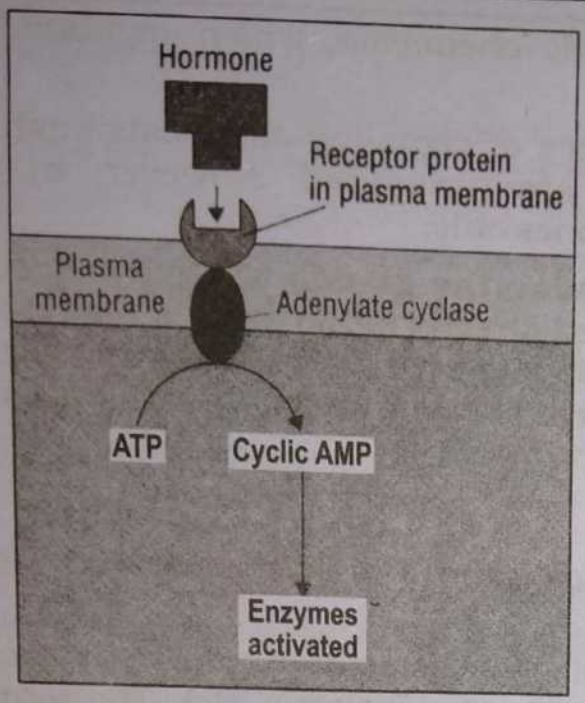
3.9.2 Hormone action:

It is to recall that why a hormone acts upon a specific cell and not the others even though it circulates in the entire body. Another question arises in mind how the target cell undergoes metabolic changes under the influence of a hormone.

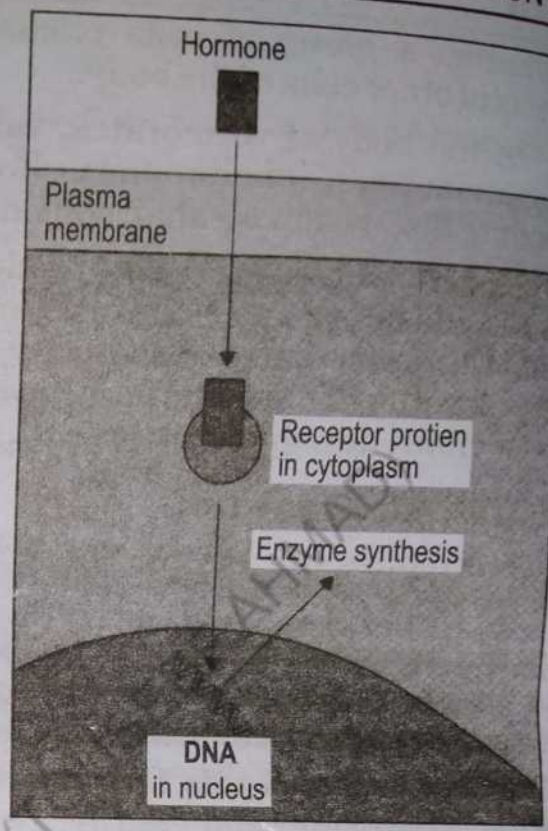
Two main models have been proposed to explain the hormone action. However, both models agree on the first step that the target cells have specific receptors in their plasma membranes.The structure of receptor has complimentary relationship with specific hormone. Thus a cell will respond to a hormone only if it possesses the appropriate receptor. The next stage --- the signal transduction pathway differs in both models.

The first model is related to peptide hormones. According to this model, the receptor molecule is linked with an enzyme, the **adenylate cyclase** on the inner side of the plasma membrane. The hormone receptor binding turns, slow adenylate cyclase into active form which converts ATP into cyclic Adenosine Monophosphate (Cyclic AMP) in the cytoplasm. The cyclic AMP serves as **second messenger**. It then activates specific enzymes which bring about the appropriate response within the cell. Several other second messenger molecules have been discovered.

The other model is related to the steroid hormones. Being fat soluble, they can directly diffuse through the plasma membrane into the cell. So they do not require second messenger. In the cytoplasm they find specific receptors which carry them into the nucleus where the hormone receptor complex directly activates the appropriate genes. Thus under the instructions of gene, enzymes are synthesized to bring about specific response.



Schematic diagram showing how hormone such as adrenaline affects its target cell.



Schematic diagram showing how steroid hormone such as progesterone is believed to affects its target cell.

Fig: 3.12

3.9.3 Feed-back mechanism:

You are already familiar with the concept of feedback mechanisms in homeostasis. Likewise, hormonal secretion is also subjected to feedback mechanism. In case of any change in chemical information of the body, the feed back mechanism comes into action and either blocks or promotes further change. The feedback is said to be **negative feedback** if further secretion of hormone is inhibited. In **positive feedback,** an increase in the concentration of a secreted hormone facilitates the process of its further secretion.

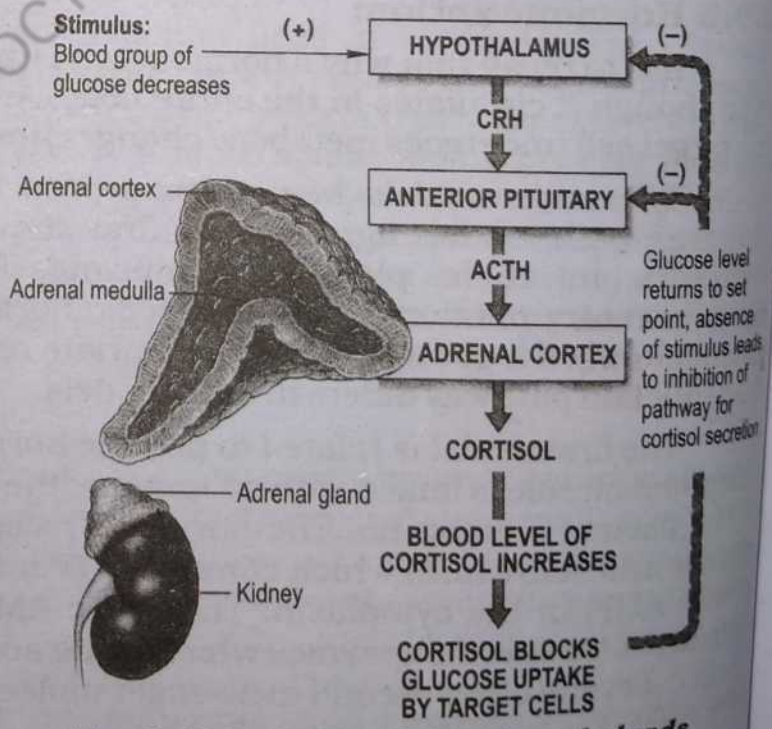


Fig: 3.13 Location of the adrenal glands

3.9.4 Mammalian endocrine system with reference to man:

Mammalian endocrine system consists of pituitary gland, thyroid gland, parathyroid gland, pancreas, adrenal gland, thymus gland, pineal gland, gonads and patches of tissues in stomach, small intestine, liver, kidneys, heart, placenta,

skin, etc. Indeed, very important to mention here is hypothalamus, a part of brain, which also serves as endocrine organ.

1. Hypothalamus:

It is an important part of the forebrain which serves as connecting link between nervous and endocrine systems. Its neurosecretroy cells produce hormones called releasing and inhibiting hormones (factors), which regulate the release of hormones from the anterior pituitary gland. The releasing hormones stimulate the release of other hormones while the inhibiting hormones cause inhibition of other hormones from the target glands respectively. Some of its cells secrete **antidiuretic hormone** (ADH) and **oxytocin,** which are actually stored in their nerve endings located in posterior pituitary gland.

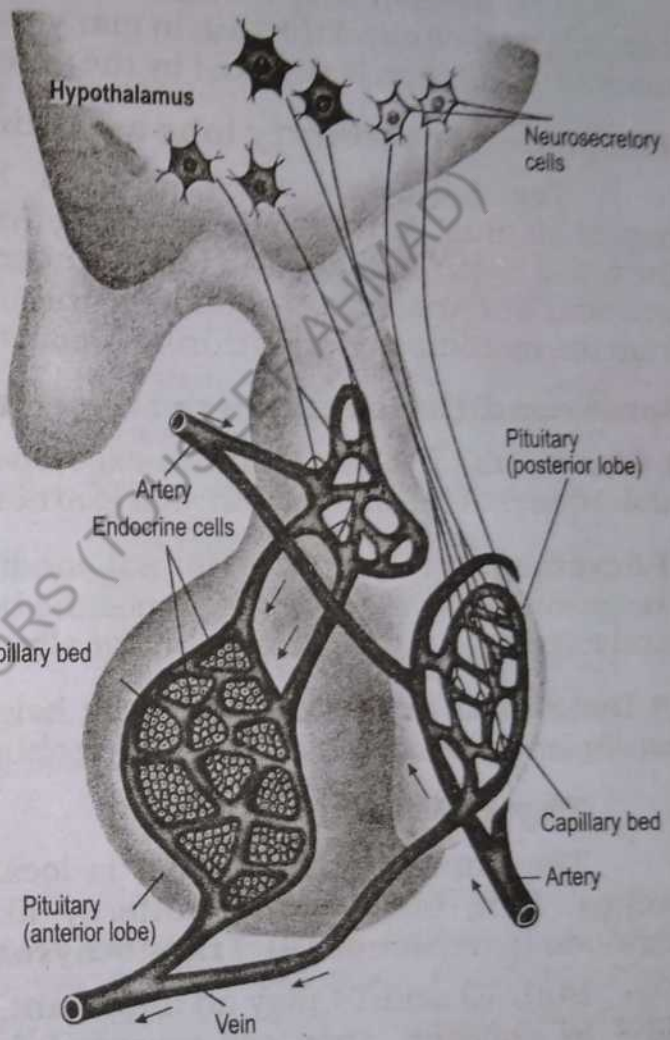


Fig: 3.14 Anatomical relationship between the hypothalamus and pituitary gland

2. Pituitary gland (Hypophysis):

It is a small pea-size structure that hangs from the base of the brain. It is attached by a short stalk of nerve fibers to the hypothalamus. Formerly, it was called as **master gland** because of the influence of its hormones on other endocrine glands. However, now we know that it is itself under the regulatory influence of hypothalamus.

The pituitary gland of most of the vertebrates including man consists of two discrete lobes an anterior pituitary or adenohypophysis and a posterior pituitary or neurohypophysis, each with a different function. In many vertebrates, the pituitary has an intermediate or median lobe also.

The anterior pituitary lobe secretions:

Under the influence of hypothalamus, it produces its own hormones which are tropic (regulate other endocrine organs) as well as others. Among the tropic hormones are thyroid stimulating hormone (TSH), adrenocorticotropic hormone (ACTH) and follicle stimulating hormone (FSH), luteinizing hormone (LH), which regulate thyroid gland, adrenal cortex and gonads, respectively. The other

important hormones of anterior lobe are somatotropin (Growth hormone = STH/GH) and prolactin. STH affects metabolism in many tissues and liver secretions that influence growth of bones and soft tissues. Prolactin is best known for stimulating and then sustaining milk production in mammary glands.

The median pituitary lobe secretion:

The median lobe secretes melanocyte stimulating hormone (MSH), which controls darkening of the skin in many vertebrates. In humans very little MSH with uncertain function is secreted by the anterior lobe rather than median.

The posterior pituitary lobe secretions:

The hormones released from here are actually stored secretion of hypothalamus. Antidiuretic hormone (ADH) increases reabsorption of water into the blood by the kidneys and therefore decreases urine output. The other hormone oxytocin stimulates contraction of the uterus during labour and release of milk from the mammary glands during breast feeding.

Some conditions related to abnormal pituitary output:

i) Gigantism: It occurs due to excessive secretion of STH during childhood or adolescence. The affected individual attains an immense height.

ii) Acromegaly: In this abnormal condition, the over-production of STH occurs after adult-hood. As a consequence the bones, cartilages and other soft tissues in hands, feet and jaws thicken abnormally.

iii) Dwarfism: In this condition the height of person remains very short due to insufficient production of STH during child-hood.

3. Thyroid gland:

The human thyroid gland is located at the base of the neck in front of trachea. It is bilobed and butterfly like in structure. It secretes **thyroxine** (tetraiodo thyronine or T4), **Triiodothyronine** (T3) and **calcitonin** hormones.

Both T3 and T4 play an important role in controlling the metabolism of the body. In children, they are essential for normal physical growth and mental development. Too much or too little of these hormonal levels in the blood can result in serious metabolic disorder for instance in case of low levels of these hormones in the blood(i.e hypothyroidism) results **myxedema** in elders which is characterized by an over weight, sluggish, dry-skinned, hair-losing, intolerant of cold, confused and depressed individual. Often thyroid is enlarged due to low intake of iodine in diet. This condition is called **goiter**. If hypothyroidism occurs in early age, it causes **cretinism** characterized by stunted growth, mental retardation and coarse facial features. In case of higher levels of thyroid hormones in the blood, hyperthyroidism is produced. It is characterized by protrusion of eye balls (exopthalmia), increased heart beat, heat intolerance, high blood pressure, profuse sweating, and weight loss.

Raised blood calcium stimulates calicitonin secretion, which causes the excess calcium to be deposited in bones.

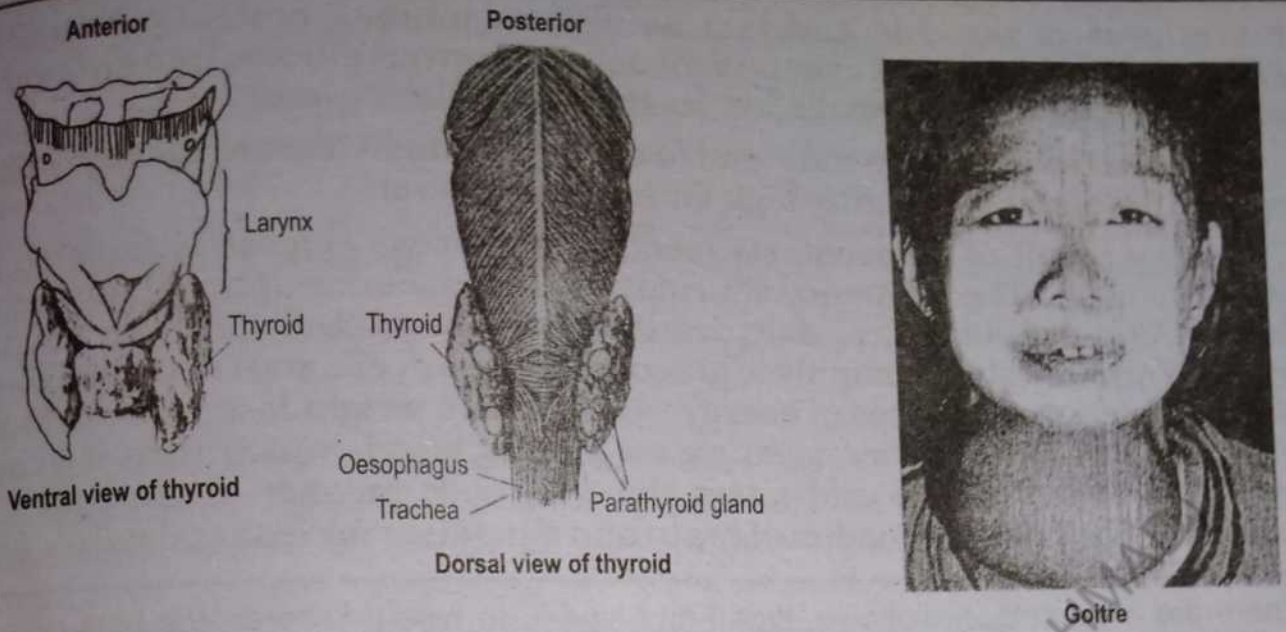


Fig: 3.15 Thyroid glands

4. Parathyroid glands:

These are two pairs of pea-size glands located dorsally adjacent to the two lobes of thyroid gland in the neck. They release **parathyroid hormone** (PTH) in response to low level of calcium in the blood. PTH increases reabsorption of calcium in the kidneys as well as it induces demineralization of osteoclasts cells of bone to release calcium in the blood.

5. Pancreas:

Most of the cells of pancreas are related to its exocrine function, i.e. secretion of digestive enzymes. However, there are patches of pancreatic cells known as **Islets of Langerhans**, which are endocrine gland. The islets consist of two distinct types of cell; **alpha cells** and **beta cells**, which secrete hormones **glucagon** and **insulin**, respectively. Both of these hormones play role in regulating blood glucose levels but their effects are antagonistic.

Glucagon is secreted in response to the decrease in blood glucose level whose set point is about 90mg/100ml. As a consequence, the glycogen and amino acids are converted into glucose in the liver to bring its level back to the normal.

Insulin is secreted in response to higher level of glucose in the blood. It stimulates liver, muscles and adipose cells for uptake of glucose. It also promotes

the synthesis of proteins and fats as well as inhibits protein conversion into glucose. It also stimulates liver and muscles to convert glucose into glycogen. As a result of these activities, insulin lowers the blood glucose level.

Deficiency of insulin may lead to a fairly common disease **diabetes mellitus** in which there is a persistantly high blood glucose level.

As a result of homeostasis mechanism excess glucose is excreted by the kidneys in urine. The frequency of urination increases disrupting the water-solute balance. As a consequence, dehydration develops and victim feels abnormally thirsty. Without a steady supply of glucose, the body cells start depleting their own fats and proteins as sources of energy. It results in weight loss. Due to the break down of fats, ketone bodies accumulate in the blood, which turn it acidic. It contributes to water loss and alters the acid-base balance of the body. Such imbalances disrupt the function of brain and if persist may lead to death.

There are two forms of diabetes, type-I and type-II. In type-I diabetes, the beta cells are destroyed by the lymphocytes. It is a consequence of an autoimmune disorder, frequently followed by a viral infection. Due to the lack of insulin, the patient is treated with insulin injections. In type-II diabetes, a more common type, the level of insulin is close to or above normal, but the target cells lose insulin receptors so gradually do not take glucose. As the affected person grows older, less and less insulin is produced. It is manifested in middle age. The victims can lead normal lives by taking low-fat and low-sugar diet and regular exercise. Sometimes oral drugs are administered to enhance insulin action or secretion.

6. Adrenal gland:

Adrenal gland lies immediately above each kidney. Each adrenal gland consists of two parts, an outer cortex and an inner medulla.

Adrenal cortex:

It works under the influence of ACTH of the pituitary gland. It produces a number of hormones collectively termed as **corticosteroid hormones** that have important effects on the body's metabolism. Important corticosteroids are as follows:

Cortisol:

They are involved in glucose metabolism and are produced during anxiety, fever and diseases. Cortisol promotes the hydrolysis of muscle proteins to amino acids which are ultimately broken down by the liver into glucose. It also reduces the inflammatory responses and pain.

Over production of cortisol results in **Cushing's syndrome** characterized by obesity, muscle wasting, hypertension and diabetes. Deficient production of hormones by adrenal gland occurs due to the destruction of adrenal gland. It is known as **Addison's disease**, which is usually a consequence of autoimmune process. It is characterized by weakness, weight loss, low blood sugar and reduced blood pressure.

Aldosterone:

It increases the reabsorption of Na^+ and Cl^- ions by the kidney maintaining blood volume and blood pressure.

The level of sodium ions plays important role in maintaining the blood pressure. During low blood sodium level, the kidneys secrete an enzyme, the rennin, which converts a plasma protein angiotensinogen to angiotensin-I. The latter is converted into angiotensin in the lungs, which stimulates adrenal cortex to release aldosterone. This is called rennin system. It affects the blood pressure in two ways, the angiotensin constricts the arteries and the aldosterone causes increased absorption of sodium. When blood sodium level is high, water is reabsorbed, and blood pressure and blood volume are maintained.

Androgens:

The adrenal cortex also produces another group of corticosteroid hormones called androgens similar to testosterone (male hormone). It is secreted in both sexes. Androgens cause development of secondary male characteristics such as the growth of facial hair, deepening of the voice and increase in muscle bulk. Excessive secretion of androgens in female lead to masculinization (e.g: appearance of beard) in ladies.

Adrenal medulla:

The adrenal medulla is under the influence of sympathetic nervous system. It secretes adrenaline (epinephrine) and nor-adrenaline (norepinephrine) under conditions of stress to bring about **fight** or **flight** response in emergency situations. They are also termed as **emergency hormones**. Epinephrine increases heart beat, blood glucose, breathing rate and metabolic rate. It constricts the blood vessels in intestine and dilates those of the muscles.

Epinephrine is sometimes given by injection as an emergency treatment in cardiac arrest, aphylactic shock and acute asthma attacks.

Norepinephrine functions like epinephrine but its primary function is to sustain blood pressure.

7. Thymus gland:

It is situated in the upper part of the chest, behind the breast-bone and consists of two lobes that join in front of trachea. It secretes several hormones including thymosin that stimulates the development and differentiation of T-lymphocytes after they leave the thymus. The T-cells defend the body against viruses and other infectious micro-organism.

8. Pineal gland:

It is a tiny, cone-shaped body within the brain. It responds to external conditions of light and darkness as sensed through the eyes. It secretes melatonin at night. The level of melatonin varies from day to night, and with the season. The variation influence the growth and development of gonads.

9. Gonads:

i) Testes: The male gonads or testes secrete androgens, the most important of which is testosterone. It stimulates bones and muscles growth and development of secondary sexual characteristics such as appearance of beard, moustache, etc.

ii) Ovaries: The ovaries secrete estrogen and progesterone. Estrogen (e.g. estradiol) maintains female reproductive system and development of the secondary sexual characteristics in female. Progesterone is primarily involved in preparation and maintenance of the uterus, which supports the growth and development of an embryo.

3.9.5 Comparison of nervous coordination and chemical coordination:

Similarities:

1. Both are means of coordination.
2. Both operate under the influence of external or internal stimuli.
3. Both are involved in homeostasis.
4. Both secrete messenger chemicals in extra cellular fluids.

Differences:

Nervous coordination	Chemical coordination
1. Faster response.	1. Slower response.
2. Communication is electro-chemical.	2. Communication is purely chemical.
3. Occurs by neurons.	3. Occurs by endocrine organs.
4. Response is shorter in duration.	4. Response is longer, mostly irreversible.
5. Secretory chemicals are released in extra cellular fluids.	5. Secretory chemicals are released in blood.
6. Chemical messengers (neurotransmitters) are short lived.	6. Chemical messengers (hormones) are long lasting.

3.10 ANIMAL BEHAVIOUR

The response of an animal in relation to its internal or external environment is called animal behaviour. It describes the way that an animal is related and interacting with the environment. Most of its interactions with its environment take place through the medium of behaviour.

It is a matter of common observation that the environmental conditions vary constantly with place and time. Moreover, the internal physiological conditions of animal are also subjected to changes. Thus in order to survive successfully, the animals have to adjust themselves by making necessary changes in their behaviour in relation to the environment. Otherwise they are likely to be perished.

The scientific study of the nature of behaviour and its ecological and evolutionary significance in its natural setting is called **ethology.** Modern studies in ethology are closely related to the disciplines of genetics, physiology, ecology and psychology.

Behaviour is based on feedback and upon machinery for response and coordination that is nervous system and effector organs.

While observing a wide variety of animal responses in the same or different stimuli, one can safely presume that all behaviours have some genetic basis because they involve nervous and effector systems. The genetic basis of behaviour were found by **Stevan Arnold** by studying the feeding preferences of coastal and inland populations of snake species in California, USA.

The concept of the genetic basis of behaviour is very simple, however, one should keep in mind that many genes are in fact influenced by the environment. So as a customarily, behaviour is identified into two types: Innate (Instinctive) behaviour and learned behaviour. Although this division is not clear-cut since animals do exhibit a range of activity in between these two.

3.10.1 Innate (Instinctive) Behaviour:

Innate behaviours are automatic, pre-programmed, genetically determined, stereotype activities, which do not involve any learning.

These behaviours are performed in reasonably complete form when an animal is exposed to the proper stimuli. Most instincts are adaptive in nature, and striking examples are web spinning of spiders, the communication of honey-bee, the smiling of a baby while looking at the face of someone, etc. Innate behaviour can be categorized into following types: Kinases; Taxes; Reflexes and fixed action patterns.

(i) Kinases:

It is an orientation behaviour in which animal exhibits random movement to a particular stimulus. In this kind, the rate of movement is related to the intensity of the stimulus rather than its direction. For example wood-lice move about quickly in dry conditions but slow down and stop in humid areas.

(ii) Taxes (Sing. Taxis):

It is another orientation behaviour, which is related to the direction of stimulus. The movement towards the stimulus is called **positive taxis** while away from the stimulus is **negative taxis**. For example, a moth flies towards the light is positive photo-taxis.

(iii) Reflexes:

It is the movement of a body part, such as knee-jerk, blinking of eye or with-drawl of hand from a hot object, etc. These are stereotyped, short-lived, rapid, responses mediated by nervous system.

(iv) Fixed action pattern (FAP):

This kind of highly stereotyped innate behaviour is triggered or released by an external sensory stimulus known as **sign stimulus** or **releaser**. A classic example is studied

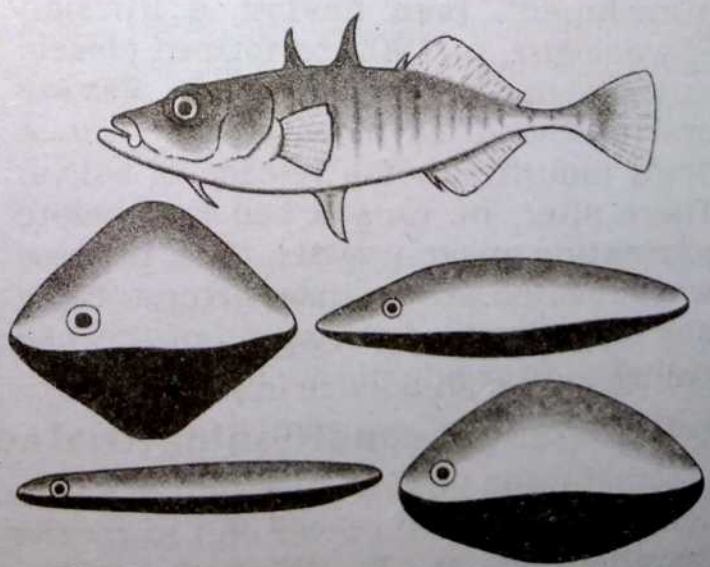


Fig: 3.16
Sign stimuli used to demonstrate FAPs

in male three- spined Stickleback fish which attacks other males that enter his territory. It was found that the releaser of the attack is the red belly of the intruder.

3.10.2 Learned behaviours:

It refers to a more or less permanent change in behaviour, which occurs as a result of experience. It differs from the innate behaviour in being acquired or modified from experience. It permits an animal to adopt quickly to the changing circumstances. There are different types of learned behaviour, such as **habituation**, **imprinting**, **classic conditioning**, **operant conditioning** , **latent learning** and **insight learning**.

(i) Habituation:

It is the type of learned behaviour in which animal stops responding to a repeated stimulus, which is neither beneficial nor harmful. It is the simplest type of learned behaviour. For example, birds feeding along a road side or perched on pole or tree along a busy highway habituate to the cars and buses passing at a few feet; city dweller people habituate to night-time traffic sounds; and country dwellers to the choruses of crickets and frogs.

(ii) Imprinting:

It occurs during very early stage in the life of birds and mammals. During this period called **sensitive period**, the animal is primed to learn a specific information, which is then incorporated into an innate behaviour. The term imprinting was coined by **Konard Lorenz** in 1930 while studying ducklings. He found that ducklings follow the first large, noisy, moving object they see after hatching. There after, they will continue to follow the same object even if their true mother is there.

(iii) Classic conditioning:

In classic conditioning or association conditioning an animal learns to give a response to an irrelevant stimulus. It is associated with reward or punishment. **Ivan Pavlov**, a Russian Physiologist, in 1902 performed classic experiment on digestion in dogs. **Pavlov** first placed dried meat powder into a dog's mouth causing release of saliva. There after, he rang a bell just before presenting meat powder. The process was repeated several time. Later, the dog started salivating at ringing of the bell rather than seeing the meat.

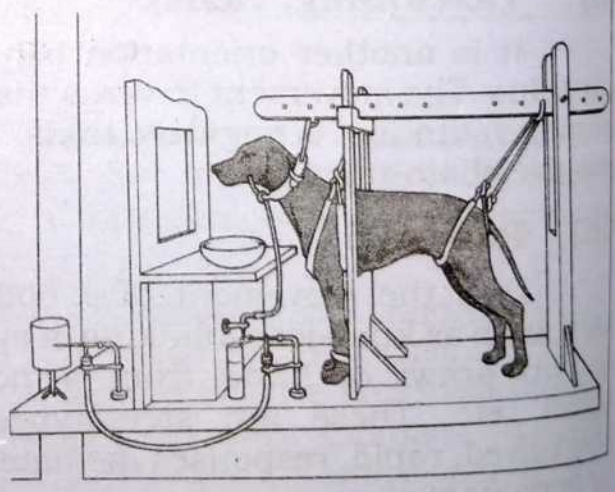


Fig: 3.17
Pavlov's experiment on conditioned reflexes

(iv) Operant conditioning (trial and error learning):

In this kind of learning an animal learns to associate one of its behaviour (such as pushing a lever etc) to receive an award or punishment. An American psychologist, **B. F. Skinner** developed a box called **Skinner box** for his experiments on conditioning with hungry pigeons or mice. Inside the box, there

was lever which operated a food supply. When the lever was pressed by the animal, a sample of food was delivered. After several accidental incidents of pressing the lever, the hungry animals learnt to press the lever at the time of their hunger.

(v) Latent learning:

The ability of rats to find their way in underground tunnels is very remarkable. If a rat is placed in a maze, it was observed that using its natural ability, the rat very soon finds its way out of the maze without being rewarded at the end of the maze. So this type of learning which is not associated with a particular stimulus and is not normally rewarded or punished, but is utilized in different situation at a later time is called **latent learning**.

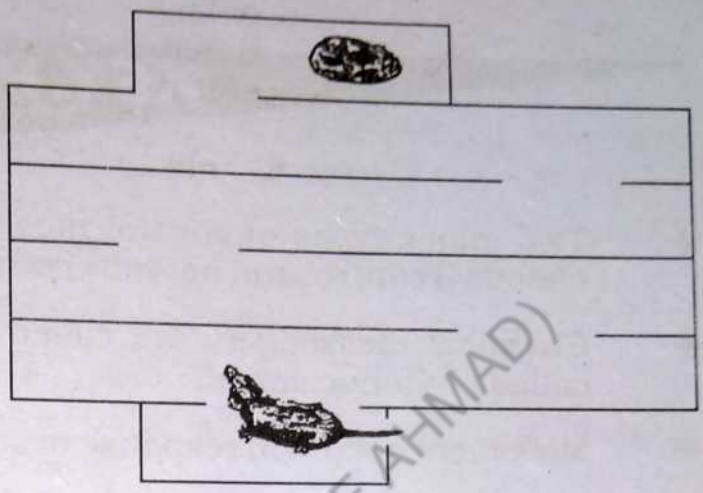


Fig: 3.18 Example of rat maze

(vi) Insight learning (reasoning):

Solving a problem without trial and error learning is called insight learning. It is the most developed form of learning behaviour. The classic experiment, which demonstrated insight learning was performed on chimpanzees. Presented with a bunch of bananas hanging too high to reach and few boxes, some chimpanzees piled up boxes to make a stand for themselves to reach the bananas.

3.10.3 Biological rhythms:

Some organisms do some activities at regular intervals irrespective of the season or day-length. This kind of behaviour is called **time biology** or **biological rhythms.** It indicates the existence of a **biological clock** within the organism. Depending upon the external or internal regulating factors, the biological rhythms can be differentiated into **exogenous rhythms** or **endogenous rhythms**, respectively. The exogenous rhythms are controlled by external changes such as 24 hour cycle of light and dark. On the other hand, the endogenous rhythms are controlled by biochemical and physiological changes within the organism. In fact, in number of examples of rhythms, it seems to be the blend of both exogenous and endogenous rhythms. Some examples of rhythms are given below.

Annual rhythmical behaviour:

Breeding seasons: Many animals do not breed all the year round. They produce young ones in season favourable for rearing and feeding.

Biannual migration: Salmons and eels migrate between sea water and fresh water more than once in their life cycles. A number of birds also have migratory life cycle.

Daily (Circadian) ryhthms : Animals are active for only part of the 24 hour cycle. For example, some function at dusk or dawn (crepuscular), some in night (nocturnal) and some in the day (diurnal).

Researchers have studied human circadian rhythms by placing individuals in comfortable, deep underground quarters, where they could make their own

schedules with no external clues. It was noted that humans seem to have a period of about 25 hours but with much individual variations.

KEY POINTS

- Two major types of control mechanism are found in living organism i.e. chemical control and nervous control.
- Chemical messengers are called hormones and the plant hormones are called phytohormones.
- Movement occurs in response to stimuli.
- Tropism is the growth response which results in curvature of plant organs.
- In nervous coordination, communication takes place by electro-chemical method.
- Nervous coordination is the fastest way of communication.
- A neuron consists of soma, dendrite and axon.
- Automatic, involuntary responses under the influence of stimuli are called reflex action.
- Cerebral cortex is the largest and the most complex part of human brain.
- Spinal cord links autonomic nervous system with brain.
- Autonomic nervous system is differentiated in parasympathetic and sympathetic nervous system.
- Parkinson's disease is caused by degeneration or damage to nerve tissue in the basal ganglia in brain.
- Neurotransmitters, pheromones and hormones have been recognized as chemical messengers.
- Responses of an animal in relation to environment are called animal behaviour.
- Innate behaviours are automatic, pre-programmed genetically determined stereotyped activities.

EXERCISE

1. Encircle the most correct choice:

i) Myelin sheath is formed by
a) Neuron b) Receptor
c) Neuroglia d) T-cell.

ii) Depolarization and repolarizations of neurolemma occur during
a) RMP b) Action potential
c) Synapse d) None of these.

iii) For the impulse to transfer from presynaptic to post-synaptic neuron, the substance required is
a) Sodium b) Potassium
c) Proteins d) Calcium

iv) Hypothalamus, amygdala and hippocampus are part of
a) Limbic system b) Thalamus
c) Corpus callosum d) Reticular formation.

v) Brain-stem consists of
a) Thalamus-Hypothalamus-Midbrain
b) Midbrain-Amygdala-Hippocampus.
c) Midbrain-Medula oblongata-Hippocampus.
d) Pons-Midbrain-Thalamus

vi) ADH and oxytocin are produced by
a) Anterior pituitary b) Posterior Pituitary
c) Pineal gland d) Hypothalamus.

vii) Both Adrenal cortex and gonads secrete
a) Cortisol b) Androgen
c) Aldosterone d) ADH

viii) The immune system is influenced by
a) Thyroxine b) Thyrotropin
c) Thymosin d) Triiodothyronine

ix) Knee-jerk is an example of
a) Taxes b) Reflex
c) Learning d) Insight learning

2. Write detailed answers of the following questions:

i) Explain the mechanism of development and transmission of nerve impulse.
ii) Discuss the anatomical and functional parts of human brain.
iii) Explain hormone action.
iv) Discuss the regulation of glucose metabolism in the body.
v) What is learning behaviour? Discuss its various types with examples.
vi) What is innate behaviour? Discuss its different categories with examples.
vii) Explain the responses of the plants environmental stresses.

3. Write short answers of the following questions :

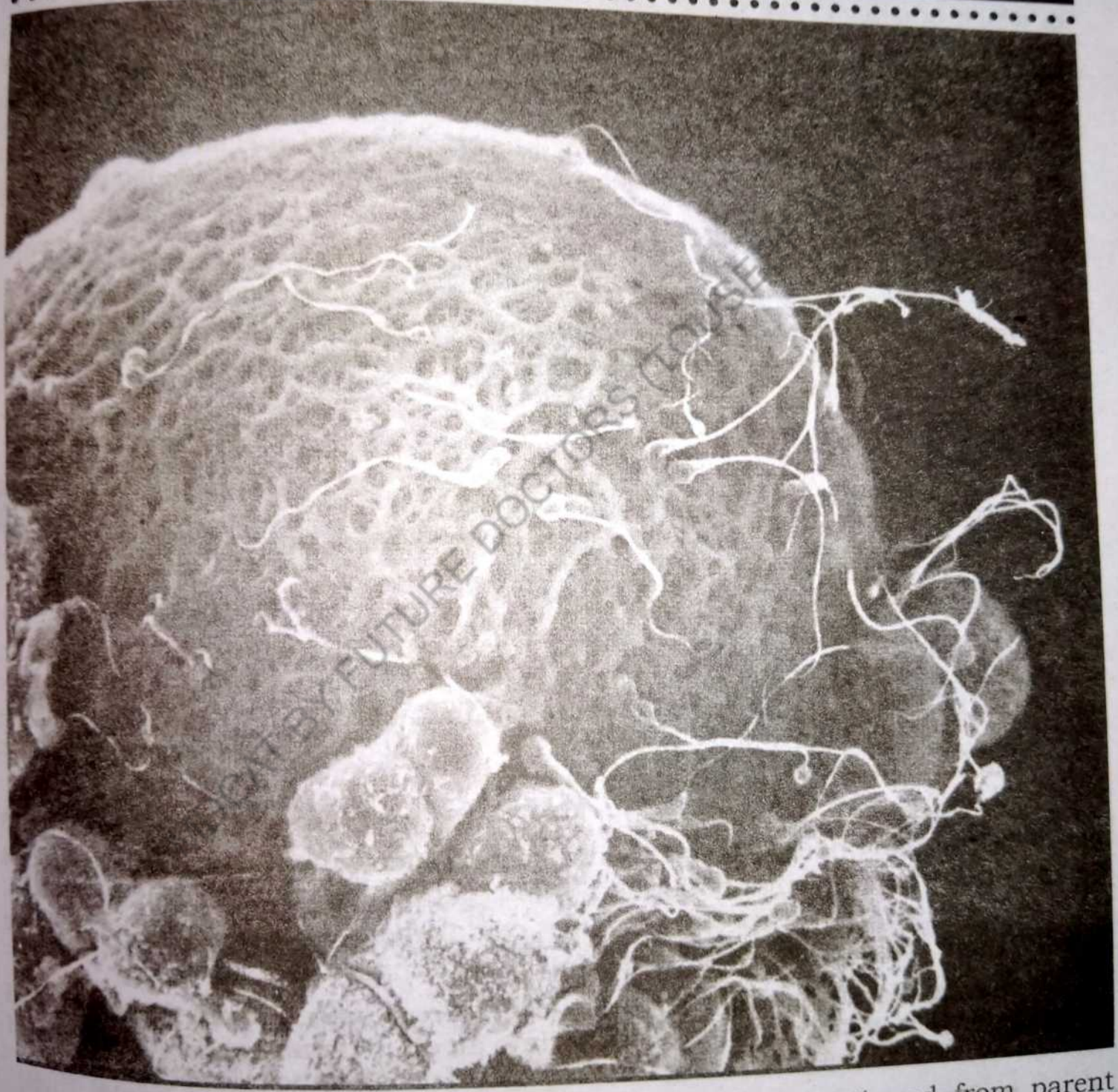
i) Write a short note on reflex action.
ii) Distinguish between CNS and PNS.
Iii) What is a receptor? What are the different types of receptors?
iv) Write short notes on Parkinson's disease and Alzheimer's disease.
v) Distinguish between peptide hormone and steroid hormone.
vi) Write short notes on gigantism, hypothyroidism, dwarfism and Addison's disease.
vii) Distinguish between innate and learning behaviours.
viii) What is imprinting?
ix) Distinguish between auxin and gibberellin.
x) What are the 1st and 2nd line of defence of plant against pathogens?
xi) How plants respond to high salt stress ?
xii) Why high heat stressed the plant?
xiii) How plants cope with herbivory stress?
xiv) Why ethene is considered as fruit ripening hormone?
xv) How plants cope with cold stress?

4. Define the following terms :

i)	Phyto-hormone	ii)	Biological clock.
iii)	Circadian Rhythum	iv)	Photoperiodism
v)	Myclin sheath	vi)	Nerve impulse
vii)	Goitre	viii)	Neuro Transmitter
ix)	Meninges	x)	Receptor

CHAPTER 4

REPRODUCTION



Life once emerged in this biosphere has been continued from parent organisms to the offsprings through a vital process, the reproduction which also ensures continuation of species itself.

We know that living things come from other living things and only life begets life. The older ones are called parents and the newly formed are called **progeny**. The process by which living things produce more of their own kind is called **reproduction**. Reproduction is not only vital for the life of an organism itself but it is much more important for the continuity of its race. It is the process of continuation of life with a fresh start. Reproduction performs yet another important function of transmission of genetic information from one generation to the next.

Through natural selection, over millions of years, a variety of ways evolved in which organisms reproduce their own kinds. There are, however, two main ways. Asexual reproduction which requires only one parent. It gives rise new individuals by mitotic division. As a result of which offspring are morphologically and genetically identical. It takes place by number of ways i.e. by spores, budding, fission, vegetative propagation, apomixis etc. and the sexual reproduction which requires two parents give rise new individuals by fusion of specialized cells called gametes. As a result of which variable offsprings are produced. It is also proved in the light of Quranic verses.

"O man kind! Be careful of your duty to your Lord Who created you from a single soul and from it created its mate and from them twain hath spread abroad a multitude of men and women. Be careful of your duty toward Allah in Whom ye claim (your rights) of one another, and toward the wombs (that bore you). Lo! Allah hath been a Watcher over you."

(Sura Al-Nisa 4, Ayah 1)

Many plants are capable of both modes of reproduction, and each offers advantages in certain situations. Sex generates variation in a population, an asset in an environment. Another benefit of sexual reproduction in plants is the seed, which can disperse to new locations and can also wait to grow until hostile environmental conditions have improved.

An advantage of asexual reproduction is that the organism increases in number very rapidly which are morphologically and genetically alike to their parent. This blocks the process of evolution and adaptation. It may destroy the survival of species at any stage. Man uses this method for the production of same type of crop or developing clones by tissues cultures.

Mitosis is the basis of asexual reproduction. It is the process that occurs when a protozoan undergoes binary or multiple fission, when a bud develops in to a branch and when new plants develop from vegetative organs like corm or bulbs. Mitosis ensures that the chromosome complement, and hence the genetic constitution, of the offspring is the same as the parent's.

In animals meiosis occurs in the formation of gametes and the sperm and ovum fuses to form zygote. This develops into an adult organism. In the process of fertilization the nuclei of the two gametes fuse to form the nucleus of the zygote.

A. REPRODUCTION IN PLANTS

There are two types of reproduction found in plant i.e. Asexual and sexual reproduction.

4.1 ASEXUAL REPRODUCTION

Naturally, plants reproduce asexually by spores, by vegetative propagation and apomixis but artificially they can reproduce asexually by cloning and tissue culture methods. Both natural and artificial asexual reproduction require only a single parent and haploid gametes are not involved in them.

1. Natural methods of asexual reproduction:

In nature, plants reproduce asexually by following methods.

(i) By spores or sporulation:

During alternation of generation plant produce haploid cell by meiosis, divide further mitotically called **spores**. These cells generate multicellular structure without fusion with another cell. The process of formation of these unicellular spore called sporulation. These spore when detach from parent plant and given favourable conditions grow into new organism. Sporulation occurs in bacteria, protozoans, algae, fungi, mosses and fern as well as in all plants.

> A single mushroom may produce 500,000 spores a minute at the peak of its production.

(ii) Vegetative propagation:

In general, vegetative propagation involves the separation of a part of the parent plant which then develop into new plant. Almost any part, root, stem, leaf or bud may serve for this purpose. They are often highly specialized for the task and bear little resemblance to the original plant organs from which they evolved e.g. Potato is actually a modified stem. In some plants, to ensure the continued survival of favourable genotype, organs of vegetative propagation also act as **perennating organs**, which lie in the soil over the winter.

(iii) Apomixis:

An entirely different mechanism of asexual reproduction has evolved in dandelions and some other plants, which produce seeds without their flowers being fertilized. This asexual production of seeds is called **apomixis**. A diploid cell in the ovule gives rise to the embryo and the ovules mature into the seeds. Which in the dandelion are dispersed by windblown fruit.

2. Artificial method of asexual reproduction:

Plant may asexually reproduce by different techniques.

With the objective of improving crops, orchards, and ornamental plants, human have divides various methods for propagation of plants by vegetative reproduction. Most of these methods are based on the ability of plants to form adventitious roots or shoots.

(i) By cutting:

Most houseplants, woody ornamentals and orchard trees are asexually reproduced from plant fragments called cutting in some cases, shoot or stem cuttings are used. At the cut end of the shoot a mass of dividing undifferentiated

cells called a callus forms, and then adventitious roots develop from the callus. If the shoot fragment includes a node, then adventitious root forms without a callus stage. Some plants including bryophyllum can be propagated from single leaves rather than stems. For still other plants, cuttings are taken from specialized storage stems. For example, a potato can be cut up into several pieces, each with a vegetative bud, or **eye**, that regenerates a whole plant.

(Ii) Tissue culture (test-tube cloning and related techniques):

Agritechnologists have adopted test tube methods to create and clone novel plant varieties. By this method, a group of genetically identical offspring produced by asexual method called **clone**. It is possible to grow whole plants by culturing small ex-plants (pieces of tissue cut from the parent), or even single parenchyma cells, on an artificial medium containing nutrients and hormones. The cultured cells divide and form an undifferentiated callus, when the hormonal balance is manipulated in the culture medium, the callus can sprout shoots and roots with fully differentiated cells. The test tube plant lets can then be transferred to soil, where they continue their growth. A single plant can be cloned into thousands of copies by subdividing calluses as they grow. This method is used for propagating orchids and also for cloning pine trees that deposit wood at un usually fast rates.

Plant tissue culture also facilitates genetic engineering in plants. Most techniques for the introduction of foreign genes into plants require the use of small species of plant tissue or single plant cells as the starting material. Test tube culture makes it possible to regenerate genetically altered plants from a single plant cell into which the foreign DNA has been incorporated. For example researchers have used recombinant DNA technology to transfer a gene for bean protein into cultured cells from a sunflower plant.

A techniques known as protoplast fusion is being coupled with tissue culture methods to actually invent new plant varieties that can be cloned. Protoplasts are plant cells that have had their cell walls removed. Before they are cultured, the protoplasts can be screened for mutations that may improve the agricultural value of the plant. It is also possible in some cases to fuse two protoplasts from different plant species that would otherwise be sexually incompatible and then culture the hybrid protoplasts each of the many protoplasts can regenerate a wall and eventually form a hybrid plantlet. One success of this method has been a hybrid between a potato and a wild relative called black nightshade. The nightshade is resistant to an herbicide that is commonly used to kill weeds. The hybrids are also resistant and this makes it possible to weed a potato field with the herbicide without killing the potato plants.

Advantages and disadvantages of tissue culture or cloning:

There are two main advantages of these forms of cloning. The first is the generation of plants for agriculture or horticulture. Vast numbers of plants can be grown in sterile controlled ensuring a much greater survival rate than seed grown plants. These plants can all be identical thus resulting a uniform crop.

Another advantage of this method is that the stock plants, raised, as they are in sterile conditions, which are completely pathogen free when, planted out by which they have developed defence mechanisms against any diseases.

Second advantage is the manufacture of use chemicals by plant cultures e.g. production of shikonin, a dye used in silk industry and in the treatment of burns, has been produced commercially.

However, there are also some disadvantages. Plants propagated in this way may be genetically unstable or infertile, their chromosomes being structurally altered or their chromosomes numbers being unusual e.g. when oil, palms produced by tissue culture were introduced by Malaysia (1970s) they turned out to be sterile.

4.2 SEXUAL REPRODUCTION

Sexual reproduction is a mode of reproduction of getting an individual from the fusion of two dissimilar sex-cells called male gamete or sperm and female gamete or ovum as a result of fertilization.

4.2.1 Different types of sexual reproduction in lower and higher plants:

i) Isogamy (Iso = same, gamos = union):

A simplest form of sexual reproduction during which morphologically as well as physiologically similar gametes fused to form zygote.

ii) Anisogamy:

A kind of sexual reproduction during which morphologically similar but physiologically dissimilar gametes fuse to form zygote.

iii) Oogamy:

A kind of sexual reproduction during which two fusing gametes are morphologically as well as physiologically dissimilar.

iv) Heterogamy (Heteros = different, gamos = union)

During a course of evolution, a very successful mode of reproduction evolved in bryophytes in which there is small flagellated motile male gamete called sperm fuses with large, non-motile food filled female gamete called ovum fuses to form zygote.

4.2.2 Salient features in the life cycle of gymnosperms:

i) The main plant is **diploid** and a sporophyte.

ii) There is **heterospory** as two types of spores are produced.

iii) The functional megaspore develops to form miniature female gametophyte which is permanently lodged within megasporangium (ovule).

iv) Female gametophyte consists of two to five archegonia each having single ovum.

v) Each microspore develops into another miniature male gametophyte consisting of stalk nucleus, tube nucleus, two male gametes and two prothallial cells within an elongated pollen tube.

vi) Fertilization takes place within sporophyte.

vii) After fertilization, megasporangium gives rise to seed.

viii) Seed undergo epigeal germination to form new sporophyte plant.

4.2.3 Sexual Reproduction in flowering plants:

Flowers develop from compressed shoots with four whorls of modified leaves separated by very short internodes. These four floral leaves, in sequence from the outside to the inside of the flower, are the sepals, petals, stamens and carpels (Fig: 4.1).

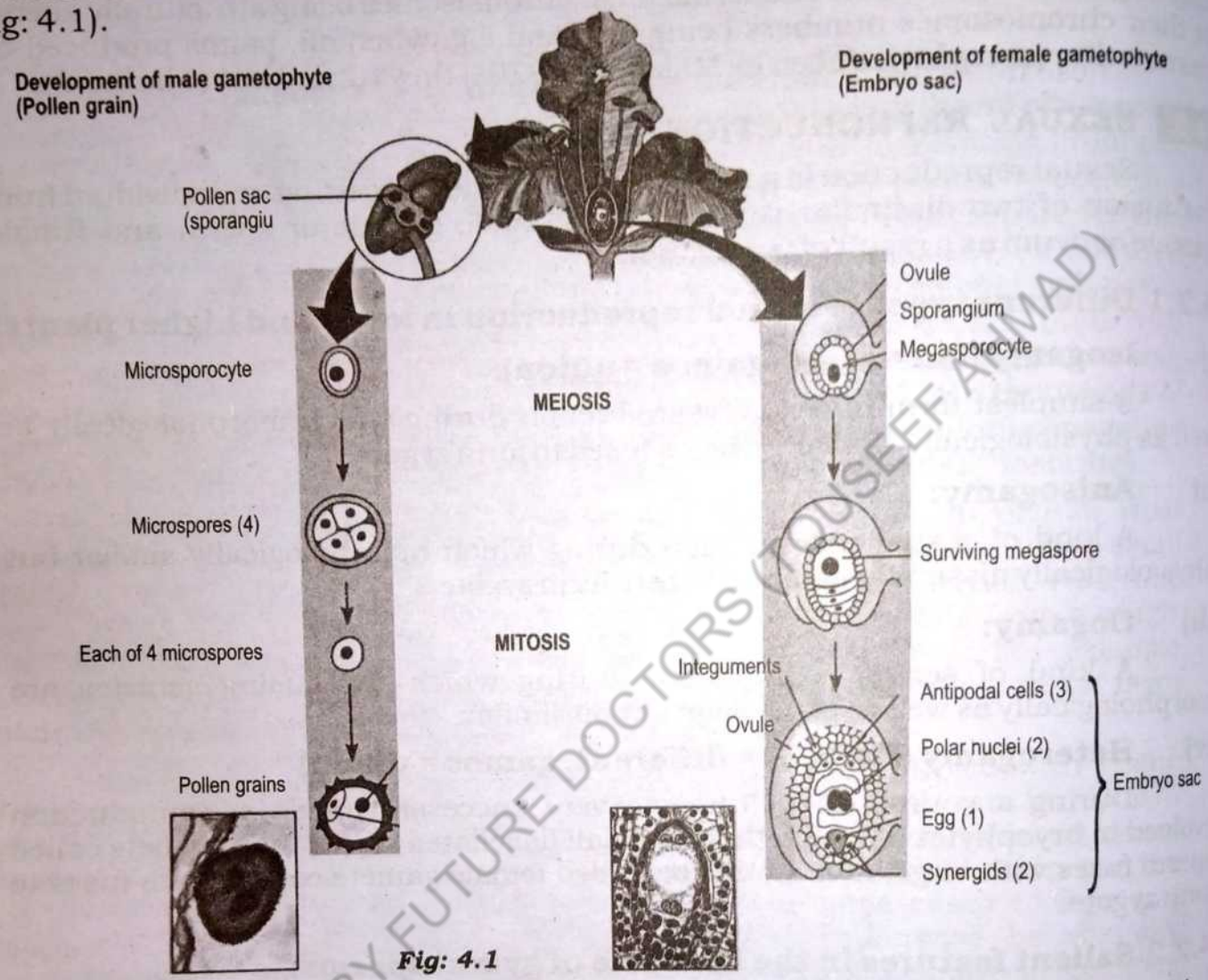


Fig: 4.1

The stamens and carpels of flowers contain the micro and mega sporangia respectively, the chambers where micro and mega spores produce respectively. These spores develop into male and female gametophyte.

The young male gametophytes are sperm containing germinated pollen grains which form within the chamber of anthers at the tips of stamens. These pollen grains after pollination develop into male gamete containg pollen tube called male gametophyte. The female gametophytes are egg containing structures called embryo sacs. Embryo sacs develop inside structures called **ovules** which are enclosed by the ovaries (the bases of carpels). Thus stamens and carpels are the reproductive organs of flowers while sepals and petals are non-reproductive organs.

Numerous floral variations evolved during the 130 million years of angiosperm history. In certain flowers one or more of the four basic floral organs- sepal, petals, stamens and carpels has been eliminated. Plant biologists distinguish between complete flowers those having all four organs and incomplete

flowers those lacking one or more of the four floral parts. For example most cases have incomplete flowers lacking petals. For example.

> Flowers are determinate shoots; their apical meristem does not continue to grow after the flower is formed. Most vegetative shoots, in contrast, are indeterminate, growing continuously.

These unisexual flowers are called **staminate** or **carpellate,** depending on which set of reproductive organs is present. (If staminate and carpellate flowers are located on the same individual plant, then that plant is said to be **monoecious** (Gr. one house) e.g. Corn. Plants having either staminate or carpellate flower. It means two sexes are present in two different plants for example **date palms.** Because dates develop only on the carpellate (female) palms, commercial date growers' plant mostly carpellate individuals. A few males (staminate plants) provide pollen enough for hundreds of females.

Anther of stamen is microsporangium on maturation it produces numerous microspores which develop into immature male gametophyte i.e. pollen grain. On the other hand ovary of carpel having ovule which is basically megasporangium responsible to produce megaspore, which develop into female gametophyte i.e. embryo sac.

Pollination:

Pollination occurs when pollen grains released from anthers and carried by wind or animals land on the sticky stigmas (though not necessarily on the same flower or plant).

For the egg to be fertilized, the male and female gametophytes must meet and unite their gametes. The first step is pollination, the placing of pollen onto the stigma of a carpel. Some plants including grasses and many trees, use wind as a pollinating agent. They compensate for the randomness of this dispersal by releasing enormous quantities of tiny pollen grains. At certain times of the year the air is loaded with pollen as any one plagued with pollen allergies can attest. Many angiosperms, however do not rely on the aimless wind to carry pollen but interact with animals that transfer pollen directly between flowers.

> The shift from wind pollination to insect pollination among the ancestors of the angiosperms was an important element in the evolutionary success of the group.

Self pollination:

Transfer of pollens from stamen of a flower to stigma of the same flower or another flower but present on the same plant.

Cross pollination

Transfer of pollens from the stamen of a flower to the stigma of anther flower present on another plant for cross pollinations, two plants are needed.

Some flowers self-pollinate, but the majority of angiosperms have mechanism that make it difficult or impossible for a flower to pollinate itself. The various barriers that favour cross pollination contribute to genetic variety by

ensuring that sperm and eggs come from different parents. Dioecious plants, of course, cannot self-pollinate because they are unisexual, being either staminate or carpellate. In some plant with perfect flowers, the stamens and carpels mature at different times. Many flowers that are pollinated by animals and structurally arranged in such a way that it is unlikely the pollinator could transfer pollen from anthers to the stigma of the same flower. Other flowers are self-incompatible; if pollen grains from an anther happens to land on a stigma of flowers on the same plant, a bio-chemical block prevents the pollen from completing its development and fertilizing an egg.

> Self-pollinated angiosperms are frequent where there is a strong selective pressure to produce large numbers of genetically uniform individuals adapted to particular relatively uniform habitats.

Pollen tubes grow down the carpels and discharge sperm into embryo sacs, resulting in the fertilization of eggs. Each zygote gives rise to an embryo and as the embryo grows, the ovule develops into a seed. The entire ovary, meanwhile, develops into a fruit containing one or more seeds, depending on the species. Fruits, carried by wind or animals, help in the dispersal of seed. If deposited in sufficiently moist soil, seed germinate; that is their embryos start growing into seedlings, a new generation of flowering sporophytes.

Role of pollen tube:

Pollen tube acts as a 'vehicle for sperms'. The evolution of pollen tubes parallels the evolution of seeds. The egg produced inside an ovule is very well protected in the ovule (megasporangium). It is so well protected that a flagellated sperm would not have the slightest chance of even reaching an egg. This obstacle has been overcome by the development of pollen tubes.

1. Development of male gametophyte (pollen):

Within the micro sporangia (pollen sacs) of an anther, diploid cells called microspore mother cells undergo meiosis, each forming four haploid microspores (Fig:4.2). Each microspore eventually divides once by mitosis and produces two cells, a generative cell and a tube cell. The two celled structure is encased in a thick, resistant wall that becomes sculptured into an elaborate pattern unique to the particular plant species. Together, the two cells and their wall constitute a pollen grain or immature male

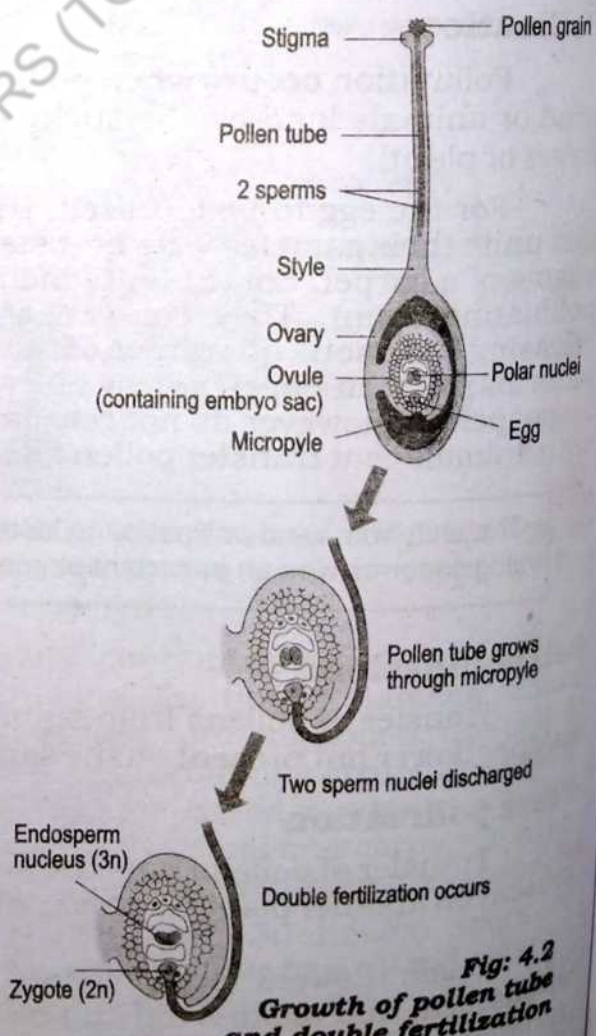


Fig: 4.2
Growth of pollen tube and double fertilization

gametophyte. After pollination and germination each microspore develop to form mature male gametophyte. The tube cell forms pollen-tube with nucleus at the tip. The generative cell divides to form two sperms. So male gametophyte consists of elongated pollen tube containing two male gametes and tube nucleus.

2. Development of female gametophyte (embryo sac):

Ovules, each containing a megasporangium, form within the chambers of the ovary. One cell in the megasporangiam of each ovule, the megaspore mother cell, grows and then undergoes through meiosis, producing four haploid megaspores. In many angiosperms, only one of the megaspores survives. This megaspore continues to grow, and its nucleus divides by mitosis three times, resulting in one large cell with eight haploid nuclei. Membranes then partition this mass into a multicellular structure called the **embryo sac**, which is the female gametophyte. At one endv of the embryo sac are three cells: the egg cell, or female gamete, and two cells called synergids that flank the egg cell. At the opposite end are three antipodal cells. The other two nuclei called polar nuclei are not partitioned into separate cells but share the cytoplasm of the large central cell of the embryo sac. The ovule now consists of the embryo sac (female gametophyte) and the integuments protective layers of sporophyte tissue around the embryo sac.

3. Double fertilization gives rise to the zygote and endosperm:

A pollen grain produces a tube at stigma when absorb nectar that extends down between the cells of the style toward the ovary (Fig: 4.3). Directed by a chemical attractant, possibly calcium, the tip of the pollen tube enters the ovary, probes through the micropyle (a gap in the integuments), and discharges its two sperm within the embryo sac. One sperm fertilizes the egg to form the zygote. The other combines with the two polar nuclei to form a triploid (3n) nucleus in the centre of the large central cell of the embryo sac. This large cell will give rise to the **endosperm**, a food-storing tissue. The union of two sperm cells with different cells of the embryo sac is termed **double fertilization**. Double fertilization ensures that the endosperm will develop only in ovules where the egg has been fertilized, thereby preventing angiosperms from squandering nutrients. After double fertilization, the ovule develops into a seed, and the ovary develops into a fruit enclosing the seed (or seeds depending on species).

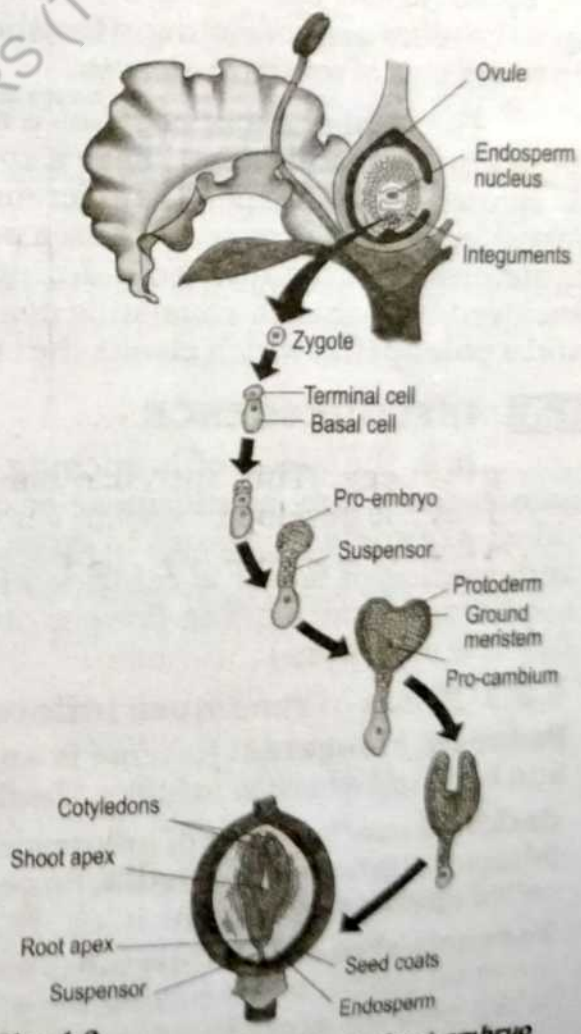


Fig: 4.3
The development of a dicot plant embryo

4.2.4 Structure of the Mature Seed:

During the last stages of its maturation, the seed dehydrates until its water content is only about 5% to 15% of its weight. The embryo stops growing and developing until the seed germinates. It is surrounded by its enlarged cotyledons, by endosperm or by both. The embryo and its food supply are enclosed by **a seed coat** formed from the integument of the ovule, the progenitor of the seed.

We can take a closer look at one type of dicot seed by splitting open the seed of a common bean (Fig: 4.4). At this stage, the embryo is an elongate structure, the embryonic axis, attached to fleshy cotyledons. Below the point at which the cotyledons are attached, the embryonic axis is called the **hypocotyl** (Gr. Hypo = under). The hypocotyl terminates in the **radicle**, or embryonic root. The portion of the embryonic axis above the cotyledons is the **epicotyl** (Gr. epi = on or over). At its tip is the plumule, consisting of the shoot tip with a pair of miniature leaves.

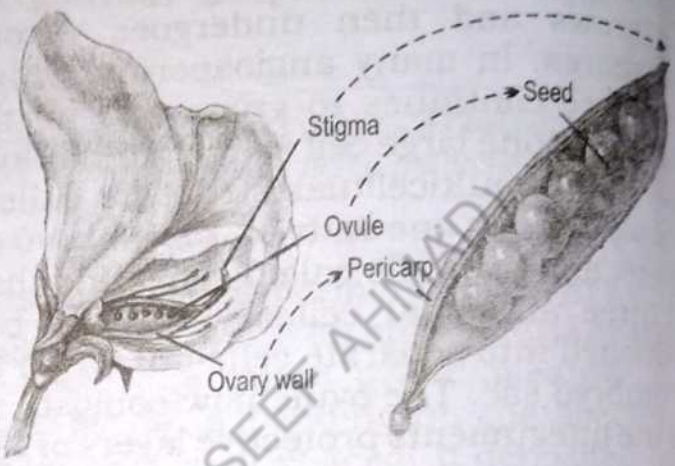


Fig: 4.4
Relation between a pea flower and a fruit

The seed of a monocot has a single cotyledon. Members of the grass family, including corn and wheat, have a specialized type of cotyledon called a **scutellum** (L. Scutell = small shield), a reference to the scutellum's shape. The scutellum is very thin, with a large surface area pressed against the endosperm, from which the scutellum absorbs nutrients during germination. The embryo of a grass seed is enclosed by a sheath consisting of a **coleorhiza**, which covers the embryolic root, and a **coleoptile**, which cloaks the embryonic shoot.

4.3 INFLORESCENCE

It is the mode of branching of floral axis having a group of flowers. The inflorescence may be racemose or cymose. In racemose inflorescence, main axis called **peduncle** continues to grow. The flowers develop in **acropetal succession** and opening of flower is centripetal. Whereas in cymose inflorescence, main axis soon stops growing. The flowers develop in basipetal succession and opening of flower is centrifugal.

4.3.1 Kinds of racemose inflorescence:

Peduncle elongated: Raceme is an inflorescence in which flowers are pedicellate and bisexual whereas in spike, the flowers are sessile and bisexual (amaranthus).

Catkin is another kind of inflorescence in which flowers are sessile and unisexual (Mulberry) whereas in **spadix**, flowers are covered over by one or many large bracts called **spathes** (Banana).

Peduncle shortened: **Corymb** is an inflorescence in which flowers have pedicels of unequal length lower having large pedicels and upper ones having small (Iberis) when pedicels are of same length of appear to arise from common point, the type is known as **umbel** (corriander).

Peduncle flattened: Head (capitulum) flattened peduncle has a mass of small sessile flowers (florets) with one or more whorls of bracts at the base forming an involucre. The florets are commonly of two kinds namely ray florets (marginal strap shaped) and disc- florets (central tubular ones) e.g. sunflower, zinnia, marigold etc.

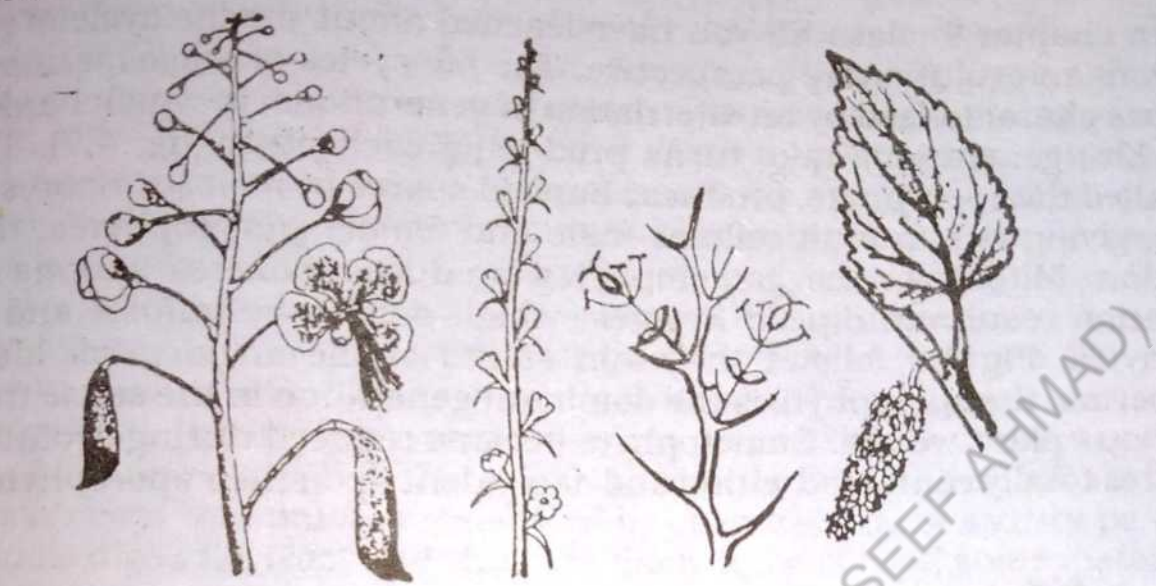


Fig: 4.5 Raceme inflorescence

Spikelet Inflorescence: It is a kind of racemose inflorescence. There are three bracts at its base called glumes. The lower two without flowers are called empty glumes. The third glume has flower in its axil and called Lemma. Just opposite to lemma, there is small bractocole called **Palea.** Flowers, are covered by their respective lemma and palea. This type of inflorescence is characteristic feature of family Poaceae.

4.3.2 Kinds of cymose inflorescence:

Uniparous (Monochasial) cyme: Main axis soon ends into a flower and produces only one lateral branch at a time ending in a flower. The succeeding lateral branches again follow the same mode of producing flowers. If the succeeding branches are produced on alternate sides, it is called **scorpioid cyme** (cotton, forget-me-not). Whereas, if the succeeding branches are produced on same side, it is called **helicoid cyme** (sundew).

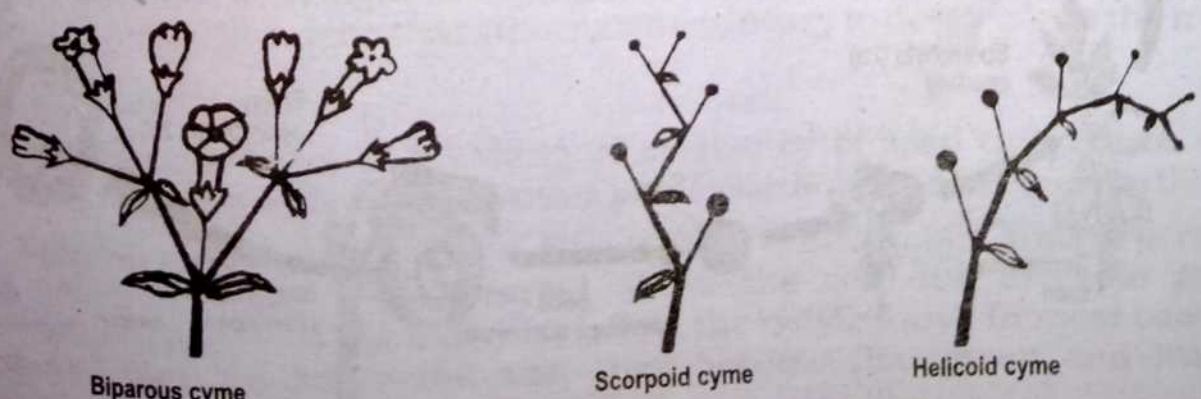


Fig: 4.6 Cymose inflorescences

Biparous (dichasial) Cyme: Main axis soon terminate into a flower and produces two flowers. This mode is followed by each succeeding flowers (Pink night-jasmine).

4.4 SPOROPHYTE AND GAMETOPHYTE GENERATIONS ALTERNATE IN THE LIFE CYCLE OF PLANT

In chapter 9 (class XI) you have learned about the life cycle of a flowering plant from an evolutionary perspective. The life cycles of angiosperms and other plants are characterized by an alternation of generations, in which haploid (n) and diploid (2n) generations take turns producing each other (fig: 4.7). The diploid plant called the sporophyte, produces haploid spores by meiosis. Spores divides by mitosis, giving rise to multicellular male and female gametophytes, the haploid generation. Mitosis in the gametophytes produces gametes sperms and eggs. Fertilization results in diploid Zygotes, which divides by mitosis and form new sporophytes. Fig 4.7 follows the main stages of the angiosperm life cycle. In angiosperms, the sporophyte is the dominant generation in the sense that it is the conspicious plant we see. Gametophyte became reduced during evolution to tiny structures totally contained within and dependent upon their sporophyte parents.

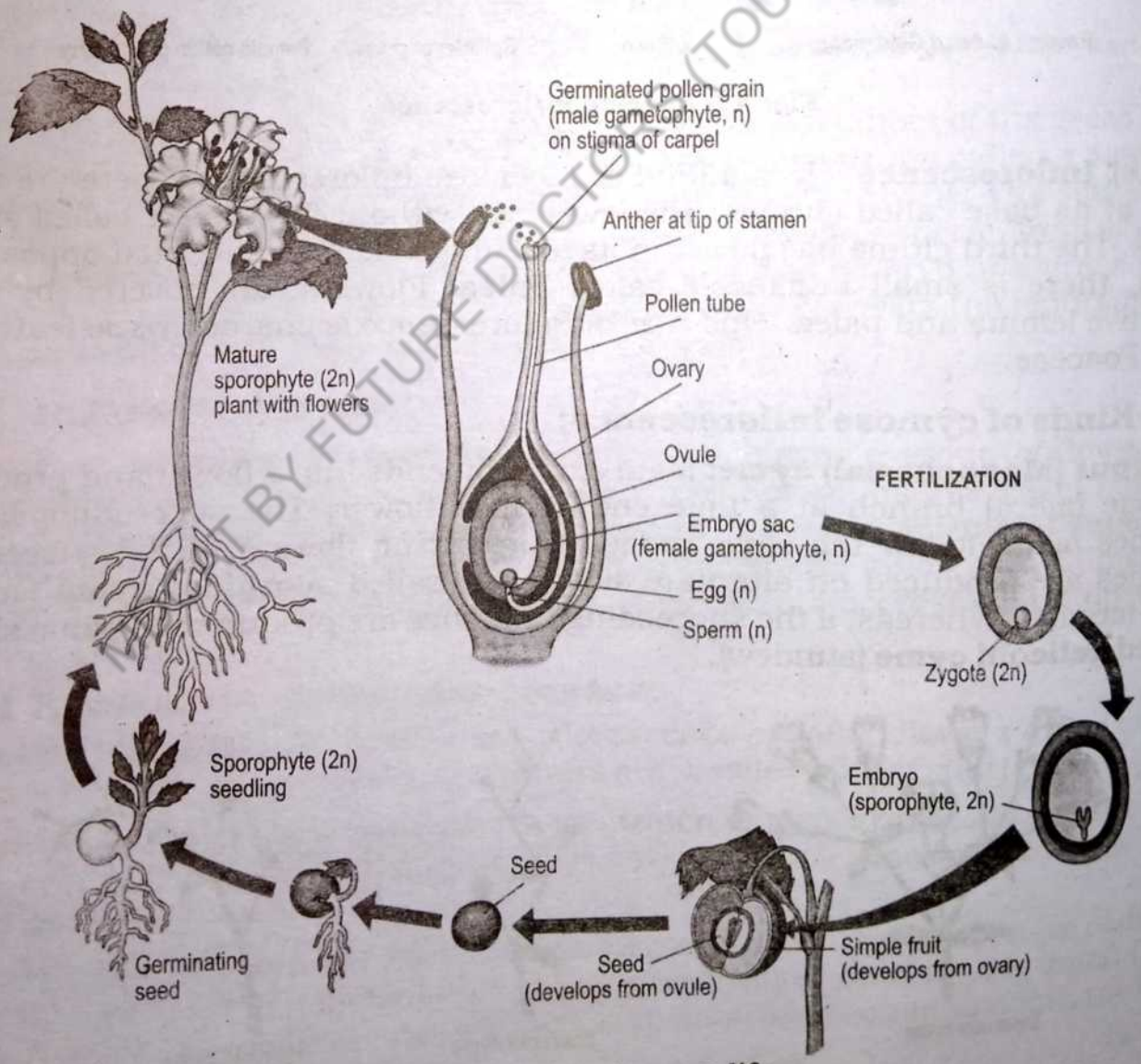


Fig: 4.7 Overview of angiosperm life

4.5 SEED DORMANCY

Dormant means sleeping or resting. Biologists use the term for a life cycle stage, such as dormant seed, that has a very low metabolic rate and is not growing and developing.

Seed dormancy increases the chances that germination will occur at a time and place most advantageous to the seedling. Breaking dormancy generally requires certain environmental conditions. Seeds of desert plants, for instance, germinate only after a substantial rainfall. If they were to germinate after modest drizzle the soil might soon be too dry to support the seedlings. Where natural fires are common, many seeds requires intense heat to break dormancy; seedlings are therefore most abundant after fire has cleared away competing vegetation. Where winters are harsh, seeds may require extended exposure to cold; seeds sown during summer or fall do not germinate until the following spring. This assures a long growth season before the next winter. Very small seeds, such as those of some lettuce varieties, require light for germination and will break dormancy only if they are buried shallow enough for the seedlings to poke through the soil surface. Some seeds have coats that must be weakened by chemical attack as they pass through an animal's digestive tract and thus are likely to be carried some distance before germinating.

The length of time a dormant seed remains viable and capable of germinating varies from a few days to decades or even longer, depending on the species and environmental conditions. Most seed are durable enough to last a year or two until conditions are favourable for germinating. Thus, the soil has a pool of ungerminated seeds that may have accumulated for several years. This is one reason vegetation can come back so rapidly after a fine, drought, flood or some other environmental disruption.

Seedless fruit-parthenocarpy:

In some plants fruit formation takes place without the process of pollination and fertilization such fruits are always seedless and described as **parthenocarpic fruits (parthenos** = virgin; **carpic** = pertaining to fruit) parthenocarpic fruits are quite regularly produced in such cultivated plants as the banana, pine-apple, some grape and orange varieties.

Treating unpollinated flowers with some phytohormones like indole acetic acid (IAA) can induce parthenocarpy. Horticulturists to bring about a good crop of fruit commonly use it. It is thought that under natural conditions the developing embryo itself produces the hormone that stimulates the ovary to develop into the fruit.

Germination:

It is the condition of breaking of dormancy of seed to produce seedling, which is the start of the life of a new young plant. Seeds can germinate into three ways:

i) **Epigeal germination** (Epi = Above; Geos = Earth) is a kind of germination during which cotyledons are carried above the soil due to rapid growth of **hypocotyl** (the region of the axis just below the cotyledons). In most cases as the cotyledons come up above the soil, they become flat, green and leaf-like in appearance, e.g. Castor oil seed.

ii) Hypogeal germination (Hypo = Below; Geos = Earth) is a kind of germination during which cotyledons are seen to remain inside the soil. It is due to rapid growth of **epicotyl** (the region of axis above the cotyledons) e.g. Maize-grain, pea, gram etc.

iii) Viviparous germination is a type of seed-germination in which seed germinates inside the fruit while still attached to the parent plant and nourished by it. The radicle elongates, swells in the lower part and gets stouter. Due to the increasing weight of the seedling. It separates from the mother plant, falls vertically in the soft mud below and gets embedded and start growing.

This type of germination is found in those plants, which grow in salt lakes, marshy places and coastal regions e.g. Rhizophora, Coconut, Palms etc.

4.6 TRANSITION TO FLOWERING STAGE

From seed to seedling:

Germination of seeds depends on **imbibition**. Imbibing water causes the seed to expand and rupture its coat and also initiates metabolic changes in the embryo that cause it to resume growth, enzyme begin digesting the storage materials of the endosperm on cotyledons and the nutritrient are transferred to the growing regions of the embryo.

The first organ to emerge from the germinating seed is the radicle, the embryonic root. Next, the shoot tip must break through the soil surface. Stimulated by light, the hypocotyl straightens, raising the cotyledons and epicotyl. Thus, the delicate shoot apex and bulky cotyledons are pulled above ground. The epicotyl now spreads its first foliage leaves, which expand, become green, and begin making food by photosynthesis. The cotyledons shrivel and fall away from the seedling.

Germination of a plant seed, like the birth or hatching of an animal, is a critical stage in the life cycle. The tough seed gives rise to a fragile seedling that will be exposed to predators, parasites, wind and other hazards. In the wild, only a small fraction of seedlings endure long enough to become parents them. Production of enormous numbers of seeds and fruits compensates for the odds against individual survival and gives natural selection ample material to screen for the most successful genetic combinations. However, this is a very expensive means of reproduction in terms of the resources consumed in flowering and fruiting. Asexual reproduction generally simpler and less hazardous for offspring than sexual reproduction, is an alternative means of plant propagation.

After germination, phase of primary growth occurs by the activity of primary meristem through mitotic cell division. Young seedling becomes young plant, with soft stem and leaves. Some plants undergo to secondary growth as result of which they increase in their girth. These growth regulated by some hormones especially Auxins upto stipulated time. Then other hormones become activated to produce reproduction parts at plant i.e. flower especially the hormone floregien.

Annual plants complete their whole growth cycle within a single year. Biennial plants flower only once, after two seasons of growth. Perennials, which may be either herbaceous or woody, flower repeatedly once they begin to do so and live for an indefinite period.

4.7 VERNALIZATION

Besides having advantageous effects of temperature on the growth of plants, low temperature plays another role i.e. vernalization which may be defined as: Promotion of flowering by a cold treatment given to the imbibed seeds or young plants. The effect of low temperature treatment applied in the earlier stages of development has an after-effect on the later stages of the development of a plant. Many plants require cold treatment for germination e.g. pine seeds will not germinate if not exposed to cold temperatures. Moreover, many cereals like wheat and rice exist in two varieties or races, the annual or spring and biennial or winter variety. The annual or spring variety is sown in spring and flowers in summer of the same year. The biennial or winter variety is sown in fall and the yield is obtained in the summer of next year. If the seeds of this variety are sown in spring, the plants do not flower and yield no seeds. It appears that low winter temperatures are necessary for the development of ears (seeds) in the winter varieties. Similarly a biennial, like turnip, sugar-beet, will not produce flowers if not exposed to cold winter temperatures.

The work of **Gassner**, **Lysenko** and others in Russia showed that if the seeds of winter wheat varieties, which are just beginning to germinate, are subjected to low temperatures of 0.5°C for a few weeks and then sown in spring will bear the fruit in the same year. In other words, they will behave like the spring varieties. Similar effects of low temperatures treatment have been observed in other biennials, e.g. sugar-beet and carrot. This phenomenon, which shortens the vegetative period and hastens flowering, is known as vernalization and has found great application in Russia and other countries in the improvement of crop production. It is now understood that certain physiological processes are triggered by this phenomenon, which induce flowering.

4.8 PHOTOPERIODISM

In general terms, this is the influence of the relative lengths of day and night on the activities of an organism. Although the best known example is flowering, many other responses in both animals and plants are regulated by day length i.e. the duration of the **photoperiod**.

On the basis of their differing responses to light and dark, flowering plants can be divided into three groups.

1) Those require long days and short nights, **long-day plants**, for example, petunias, spinach, radishes and lettuce. Long-day plants flower only when the light period exceeds a certain critical length in each 24-hour cycle. This varies, but on average is about 13 hours to 14 hours.

2) Those that require short days and long nights, **short-day plants,** for example, chrysanthemums, poinsettias, cocklebur. Short-day plants flower only when the light period is shorter than a critical length in each 24-hours cycle, For cocklebur this is 14 ½ hours.

3) Those that are indifferent to day-length, day-neutral plants, for example, tomato and cotton.

From the leaves, the message is transmitted to the buds where flower formation is initiated. That the message takes the form of a hormone has been demonstrated by indigenously grafting two short-day plants together. A plant which has been allowed to flower by exposure to short days is joined to another plant which has been prevented from flowering by being kept in long-day conditions. The result is that the latter blooms. The hormone has been named **florigen**, but so far it has not been isolated.

4.8.1 Mechanism involving light quality and biological clock:

To measure daylight, a plant needs some sort of metabolic clock to measure time (how long it has been light or dark) and **light detecting system** to set the clock. Virtually all organisms have an internal **biological clock** that in some way (usually poorly understood) measures time even without environmental clues. However, environmental clues, and particularly light, can reset the clock.

4.8.2 Flowering hormone florigen and phytochrome:

Many plant processes are influenced by light. Before a plant can respond to variations in light intensity, duration or wave length it must first detect these changes, some form of photoreceptor is necessary if a relationship establish between a pigment called Phytochorme and a number of light induced plant responses.

Phytochrome, isolated in 1960, exists in two interconvertible forms.

1) **Phytochorme 660 (P^{660}):** This absorbs red light (Peak absorption at a wavelength of 660 nm)

2) **Phytochrome 730 (P^{730}):** This absorbs light in the far red region of the spectrum (Peak absorption at 730 nm).

Phytochrome comprises a protein and a pigment. It is distributed throughout the plant in minute quantities, being most concentrated in growing tips. The action of two forms are usually antagonistic i.e. where P^{660} induces a response, P^{730} inhibits it. The various effects of the two forms are listed in table.

Table 4.1 Summary of the effects of red light and far-red light

Red light effects	Far-red light effects
Phytochrome 660 changes to phytochrome 730	Phytochrome 730 changes to phytochrome 660
Stimulates germination of some seeds, e.g. lettuce *(Lactuca)*	Inhibits germination of some seeds, e.g. lettuce *(Lactuca)*
Induces formation of anthocyanins (plant pigments)	Inhibits formation of anthocyanins
Stimulates flowering in long-day plants	Inhibits flowering in long-day plants
Inhibits flowering in short-day plants	Stimulates flowering in short-day plants
Elongation of internodes is inhibited	Elongation of internodes is promoted
Induces increase in leaf area	Prevent increase in leaf area
Causes epicotyl (plumule) hook to unbend	Maintain epicotyl (plumule) hook bend

Most of the flowers are formed at this apex, experiments confirm that light stimulus is detected by the leaves. In some cases only a single leaf needs to be subjected to the appropriate stimulus to induce flowering. A message must therefore pass from the leaves to the apex. As plants co-ordinate by chemical means, this message is assumed to be a hormone and has been called **florigen**.

4.8.3 In vitro is fertilization of plant egg and its importance:

In vitro said to be a biological techniques or process; performed outside a living organism in an artificial environment created by means of scientific equipment.

Early efforts in this field involved dissecting out whole ovules and placing them in a suitable nutrient solution. If this is done carefully, the egg (Zygote) within usually will develop into a mature embryo. When an ovule is taken from an ovary and placed in a nutrient solution, it exhibits complex nutrient requirements.

Once the embryo is mature, it is autotrophic from that point on, it will grow and develop normally if it is simply kept at a favourable temperature and provided with water and oxygen. Earlier however, when it is still heterotrophic, growth and development will not occur, even if the embryo is supplied with sucrose and the necessary mineral nutrients. In addition young embryos will grow to maturity only if they are supplied with substances that the embryo needs to develop properly. The older an isolated embryo is, the better its chances for normal growth and survival will be.

Embryo culture techniques are important in the development of new crops, they allow the development of plants with a much wider range of genotypes that would be possible of the embryos remained attached and developed normally since the chances of survival for unusual genotypes are greater in culture.

B. REPRODUCTION IN ANIMALS

The process in which one or two parent organisms form a new individual is called reproduction. Reproduction unlike other systems of the body is not essential for the life of parent itself. An organism can survive well even without reproducing but if the reproductive function in all the members of a species stops and the new ones are not produced, the whole species will vanish.

> Reproduction preserves the species as a whole rather than the individual organism.

There are a variety of ways through which reproduction takes place in animals. These various patterns, however are classified under two main modes called Asexual reproduction and Sexual reproduction.

4.9 ASEXUAL REPRODUCTION

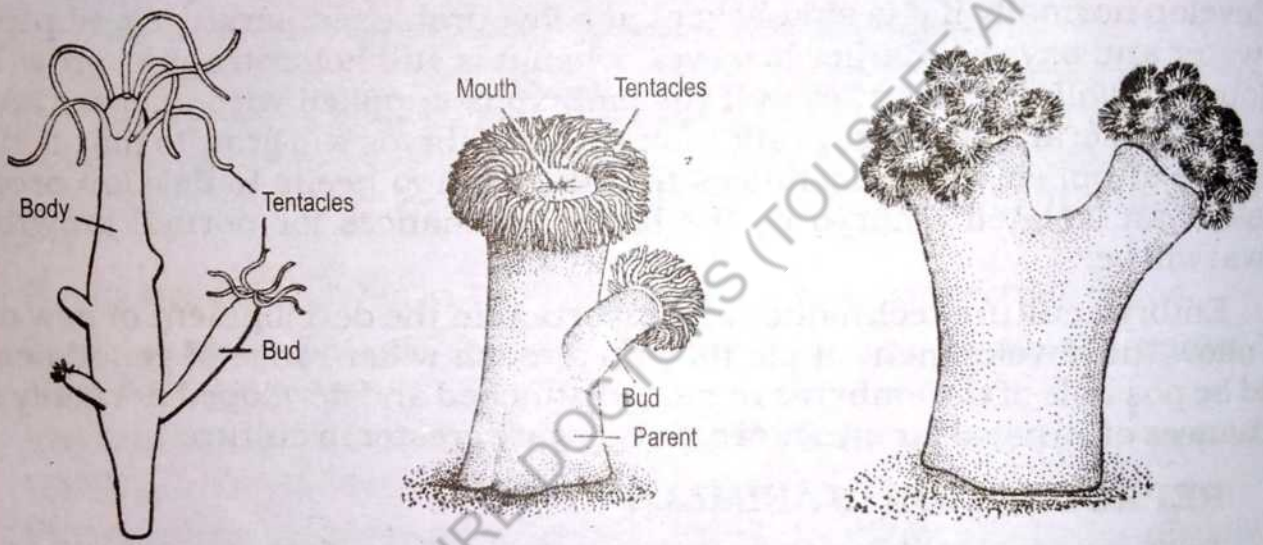
This is the primitive method of reproduction by which a new organism is formed from just one parent without the participation of mate, gamete or fertilization. The offsprings produced by this method are the exact copies and thus identical to their parents and no variations are seen because all the offsprings are genetically identical to their parents.

Asexual reproduction occurs in many ways. The common types in animals are, however, **fission, budding, regeneration** and **parthenogenesis.**

Fission: This is the simplest method of asexual reproduction in which the parent body divides into two or more parts and each of which develop into a new individual. The process is called **binary fission** if parent body divides into two and **multiple fission** if it divides into more than two daughter organisms. Fission is common in many protoctists like *Amoeba, Plasmodium, Paramecium.*

Budding: In this process, a small outgrowth develops on some part of the parent body and is called a **bud**. The bud starts growing and when all the specialized cells and tissues are formed, it now looks like a small individual which breaks off, starts an independent life and grows to adult size. Budding is common in sponges, hydras and corals, being more common in species, which form large colonies.

Asexual reproduction produces exact copies whereas sexual reproduction brings variety



Hydra showing stages of budding

budding in *Metridium*

A stage in longitudinal binary fission in *Metridium*

Fig: 4.8

Regeneration: This is the process of re-growing the missing parts, which have been lost by accident or when the animal is cut in laboratory. It is common in worms where head end develops a new tail and the tail end develops a new head part. Same happens in many echinoderms. Because new organisms can be formed in this way, sometimes it is said that animals can reproduce by regeneration.

Sponges, sometimes, undergo a similar process called **fragmentation**. In this process pieces of parent body split off and grow into new complete sponges.

Parthenogenesis: This is the type of reproduction which is neither strictly asexual nor sexual. Although like sexual reproduction gametes are produced but like asexual reproduction it requires only one parent, a female, who produces eggs that develop into adult without fertilization. Parthenogenesis is common in some insects like honey-bees, ants and wasps.

Cloning: Cloning is an uncommon but recent technique of a special type of reproduction. Technically this is an asexual type of reproduction because

formation of the new individual requires only one unfertilized egg whose nucleus is replaced by the diploid nucleus of a somatic cell. This egg is lodged in the uterus of a female where it behaves like a fertilized egg and develops into an organism, which is an exact copy of the parent who donated the diploid nucleus.

Cloning has many advantages and disadvantages. Advantages include the formation of exact replica of a parent and use of vital organs of clone for transplantation, better crops, selected livestock etc. and formation of copies of near and dear ones.

Cloning of man will however lead to a number of social implications like the determination of relationships of clone, like his legitimacy and status particularly in a muslim society and the fear of making many identical copies of criminals.

The first cloned sheep was given the name "Dolly".

Twins: Twins are the two children which develop and are born together. Twins are of two types i.e. **Identical twins** and **fraternal twins**. Identical twins are exactly alike and of the same sex because both of them develop from just one zygote **(monozygotic)** which somehow divides mitotically into two separate blastomeres, each of which develops into a new individual. As both of these develop from one zygote they share the same genes, and thus are of the same sex and exactly identical in features. Being the product of mitosis, identical twins are often said to have developed asexually. Fraternal twins on the other hand are the children which develop from two independent eggs. As each egg is fertilized by a separate sperm they are **dizygotic** and thus the genotype of each zygote is different hence they are not identical and are said to be the product of sexual reproduction.

4.10 SEXUAL REPRODUCTION

Sexual reproduction is the primary mode of reproduction in animals, though a few lower animals can reproduce asexually.

It is the type of reproduction which involves sex cells, the gametes. A male gamete, the sperm, fuses with a female gamete, the ovum, to form a zygote which undergoes development and a new individual is formed. This type of reproduction involves two parents, a male who contributes the sperm and a female who contributes the ovum.

4.10.1 Significance of sexual reproduction:

Why sexual reproduction is the predominant type of reproduction among animals? Even among animals that reproduce predominantly asexually do at times switch over to sexual mode of reproduction.

Sexual reproduction is important to avoid **genetic monotony**, which is the result of asexual reproduction where generation after generation exactly identical progeny develops. Sexual reproduction, on the other hand, produces an endless variety of organisms because each organism develops from a unique set of characters coming from different parents. This diversity of characteristics in a species helps a lot of organisms to adapt the ever-changing conditions of the habitat of an animal. Thus the chances of survival of a species are far more bright

in an unfavourable environment or during the outbreak of disease. The genetic variation thus produced by sexual reproduction is the foundation of evolutionary changes. In our common life these variations help in the identification of different members of a species because they are not exactly alike as the case is with the progeny of an asexual reproduction.

4.10.2 Necessities of sexual reproduction:

Sexual reproduction requires (i) Gametogenesis, (ii) Mating and (iii) Fertilization.

1. Gametogenesis:

It is the process of formation of sex cells, the gametes. In all animal species except sponges, it takes place in special reproductive organs, the gonads. Male gametes are called **sperms** and female gametes are called **ova** or eggs. Gametes are derived from the special type of cells called **germ cells** lodged in the gonads. Gametogenesis is of two types, **spermatogenesis** and **oogenesis**.

> Gametes are always haploid that is with half the species number of chromosomes.

Spermatogenesis: It is a process of cell division by which sperms are formed from **germ cells** present in male gonads, the testes. Germ cells present in testes first transform mitotically into **spermatogonia** and then into **primary spermatocytes**. Each primary spermatocyte divides meiotically into two **secondary spermatocytes** which on their turn further divide to form four genetically different haploid **spermatids** each of which ultimately develops into a **sperm**. The entire process takes about ten weeks to be completed.

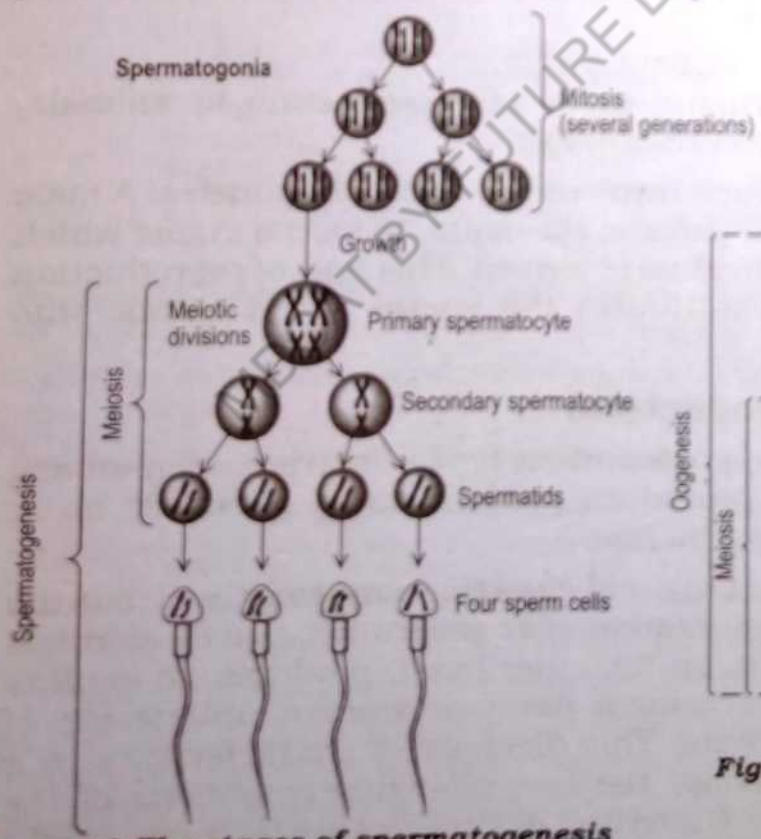


Fig: 4.9 The stages of spermatogenesis

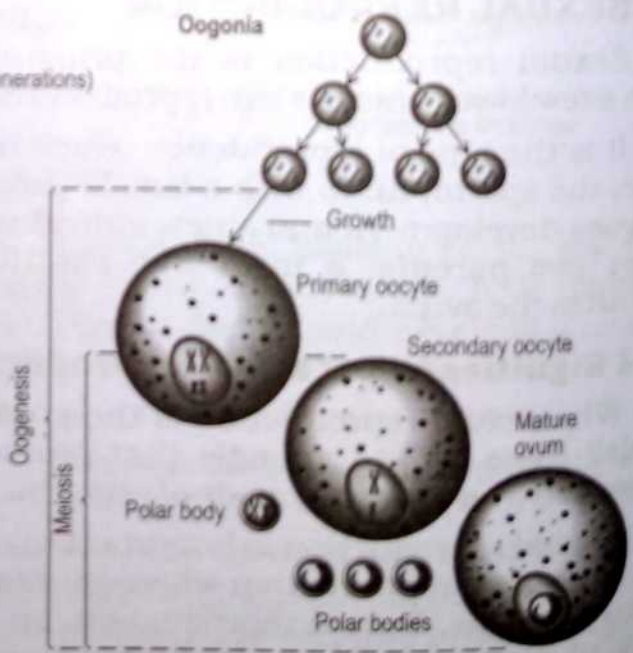


Fig: 4.10 The stages of oogenesis

Oogenesis: It is a process of cell division by which ova (eggs) are formed from **germ cells** present in the female gonads, the ovaries. Germs cells in ovary divide mitotically to form **oogonia** which develop into **primary oocytes**. The latter undergo first meiotic division to form two unequal cells, a larger **secondary oocyte** and a smaller **polar body**. Each of which further divides to form a large haploid **ovum** or **egg** and three haploid polar bodies, which remain small and non-functional and disintegrate. The entire process completes in about a month.

Mating and fertilization:

Mating is the process in which male and female contribute their gametes for the process of fertilization, formation of a diploid zygote and its further development into an offspring either inside the body of female like mammals including human beings or outside the body like fish, frog etc.

Fertilization may be external or internal.

External fertilization:

This is the process of fusion of a sperm and ovum outside the body of female in an aquatic medium. It is more common in lower animals and especially those that are sessile. During mating sperms and eggs are discharged, at the same time, in water where eggs are fertilized by sperms. Among higher animals most of the fishes and amphibians like frog exhibit the process of external fertilization.

External fertilization cannot take place outside water.

Internal fertilization:

In this case, the eggs are fertilized inside the body of the female. Internal fertilization is a rule in all terrestrial animals though many aquatic species also exercise internal fertilization. As the eggs are protected inside the body of the female and chances of fertilization are much brighter, the number of eggs produced in such animals is far less than those who lay their eggs in water.

Sex types (Unisexual and Bisexual animals): Most of the animals have a distinct sex they are either male or female having testes or ovaries respectively. Such animals which have only one type of gonads are said to be **unisexual** or **dioecious** or **heterophrodite**.

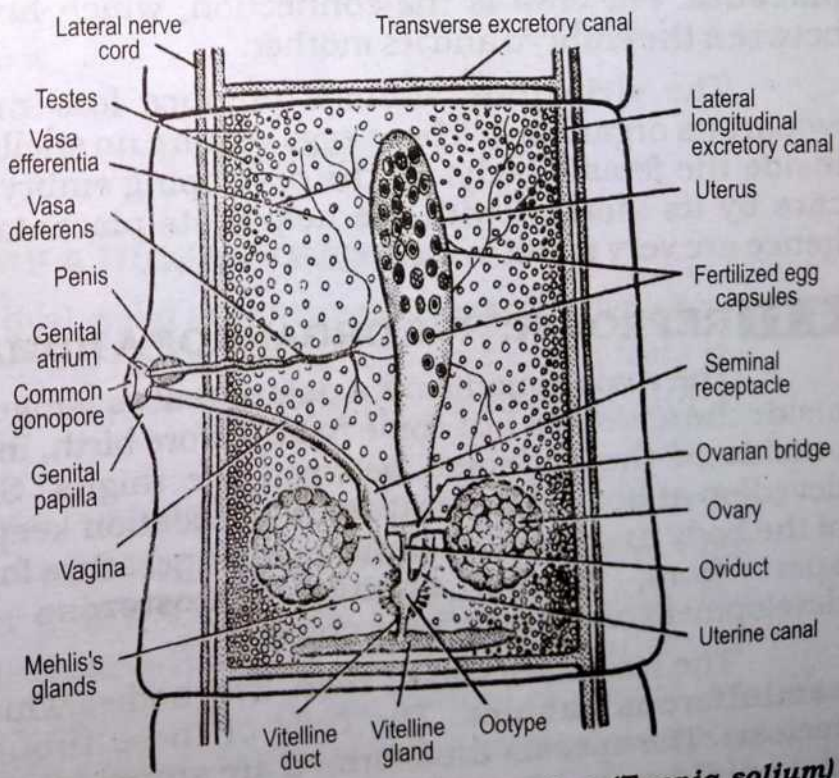


Fig: 4.11 Hermaphrodite organism (Taenia solium)

Many invertebrates do not fit in this category and they are male as well as female. In such animals, both the types of gonads i.e. testes and ovaries not only develop but are functional in each of these individuals. Hence, they produce both sperms and ova. Such animals are said to be **hermaphrodite** or **bisexual** or **monoecious**. This is particularly true of worms and parasites like liver fluke and tape worms. Though sperms and ova are produced in the same individual, even then in most of the hermaphrodites **cross fertilization** takes place that is their eggs are not fertilized by their own sperms but by the sperms of another individual and vice versa. Under certain conditions like isolation **self-fertilization** however may take place.

Oviparity: The female gametes called eggs or ova are produced in the ovaries located inside the body of a female. In most of the animals the eggs are laid in their environment. Such animals are called **oviparous**. The eggs may have already been fertilized, before being laid, (internal fertilization) or fertilized after they are laid (external fertilization).

Eggs of oviparous animals are usually large in numbers and in terrestrial animals, the eggs are always protected by tough water proof shells, which are permeable to gases. Shells protect them from being dried out. The eggs of aquatic oviparous animals being laid in water, are however, covered over simply by gelatinous membranes. The eggs of oviparous animals are also large in size because they contain enough stored nutrients or yolk for the embryo, which completes its development inside the egg before hatching out.

Viviparity: The animals who don't lay eggs but retain them inside their body, where they are fertilized and develop, are called **viviparous**. These animals give birth to live young ones. Most viviparous animals, including human beings, are mammals in which needs of the developing embryo like supply of food and oxygen and removal of the wastes it produces are carried out by a special organ the **placenta**. Placenta is the connection, which helps in exchanging the materials between the embryo and its mother.

The viviparous animals produce less number of eggs as compared to oviparous organisms. These eggs require no shells because they are well protected inside the female body. As the developing embryo in viviparous animals is taken care by its mother, with the help of its placenta, their eggs need little yolk and hence are very small in size.

4.11 REPRODUCTIVE ORGANS OF A HUMAN MALE

The male gonads are a pair of **testes** (singular-testis). Though they develop inside the abdomen but come to lie, before birth, in **scrotum** a pouch of skin located outside of the abdomen between the thighs. Since the sperms are unable to devedlop at body temperature. This location keeps the testes cooler than the core of the body and provides optimum temperature for sperm development. The testes apart from, sperms produce **testosterone** hormone, which controls the development of secondary sex characters.

The testes are small, solid, oval bodies which are packed with tightly coiled **seminiferous tubules**. The cells of these tubules produce haploid sperms by meiosis. The sperms thus formed are stored in an about 6 metres long, thin tube, the **epididymis** where they undergo complete development and become motile.

Epididymis forms a coil compact mass, which lies attached to the testis. The sperms leave epididymis through a duct called the **vas deferens,** which opens into **urethra**. The urethra is a tube, which comes from the bladder runs through and opens at the tip of a copulatory organ, the **penis.** The penis and **scrotum** constitute the **external genitalia**. The urethra also called **urinogenital duct** is a common tube for the urinary and reproductive discharge.

The male reproductive organs also include three type of glands whose secretion mixes with sperms to form the male genital fluid called the **seminal fluid** or simply the **semen**. This fluid provides the sperms with food and a medium to swim in. It also neutralizes the acidity of urethra caused by the passage of urine.

Human testes are packed with about 500 seminiferous tubules which produce about 30 million sperms everyday.

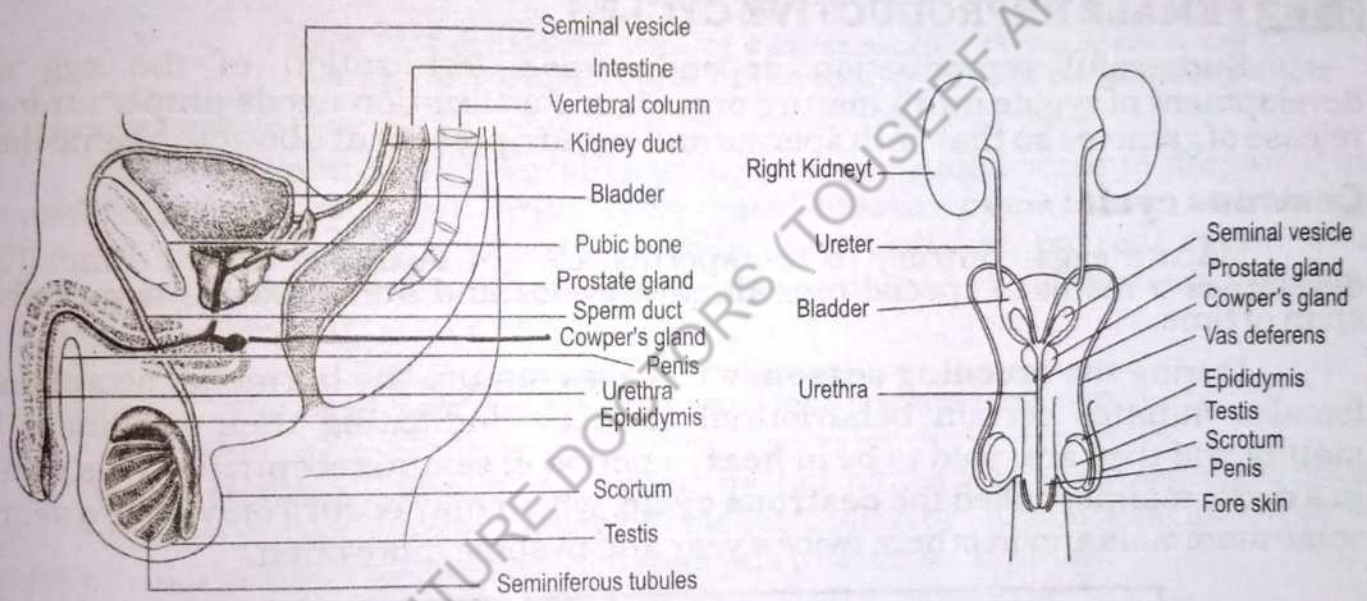


Fig: 4.12 The reproductive organs of a human male

4.12 REPRODUCTIVE ORGANS OF A HUMAN FEMALE

The female gonads are a pair of oval, solid structures the **ovaries**, which are present in lower part of body cavity. During ovulation one egg is released from the alternate ovary into the body cavity, which is immediately sucked up into an **oviduct**.

Oviducts are a pair of tubes, each opening on one side into the body cavity near the ovary of its own side by a ciliated **fallopian funnel** for entry of ova. Both the oviducts open at their other end into a small pear shaped muscular but distensible sac, the **uterus** in which the embryo develops. The outer muscular wall is myometrium and the inner spongy endometrium. At the bottom of uterus is a narrow opening the **cervix** that leads into a muscular tube called **vagina,** which is used for the reciaption of sperms and delivery of foetus.

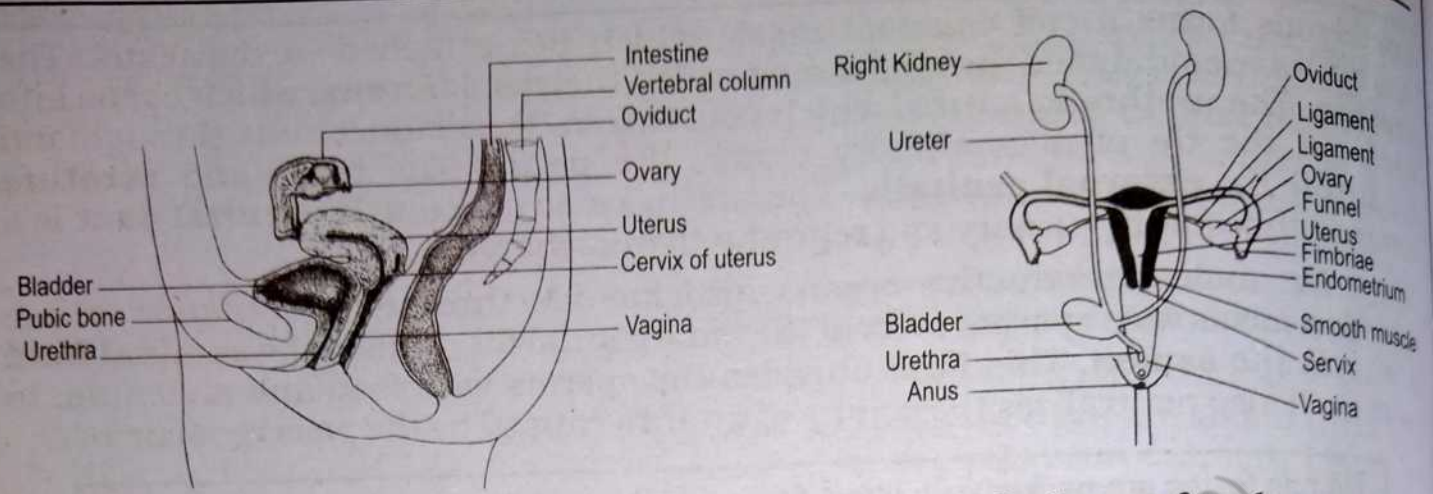


Fig: 4.13 The reproductive organs of a human female

4.13 FEMALE REPRODUCTIVE CYCLES

Successful reproduction depends upon fertilization of the egg and development of zygote into a mature organism. Fertilization needs proper timing of release of gametes so that both sperms and egg are present at about the same time.

Oestrous cycle:

Mature eggs contrary to the sperms are not available all the time. They develop as a result of special reproductive cycles and are viable for a very short span of time.

During the **breeding season**, when eggs mature the hormonal secretion in females initiates certain behaviourial changes, indicating their readiness for mating and they are said to be in **heat**, a period of sexual receptivity. This occurs in a cyclic manner called the **oestrous cycle**, which may occurs only once a year in some mammals and in others twice a year and in some more often.

> Oestrous cycle ensures that mature egg is available for fertilization.

The reproductive cycle in human females is brought about by an ovarian cycle followed by a menstrual cycle, both of which are under the control of hormones.

Ovarian cycle:

At the onset of **puberty** (sexual maturity), in her early teen years, a human female has around 200,000 oocytes in each of her ovary. During a female's fertile years only about 450 of these oocytes develop into mature eggs.

When female is about 50 years old, she reaches **menopause**, the end of fertility. Human females do not undergo a seasonal oestrous cycle as lower mammals do, instead one egg is released from an ovary once about every 28 days. This is often called **ovarian cycle**. Between the puberty and menopause, oocytes in the ovary undergo oogenesis and during each monthly ovarian cycle usually a single egg matures and is released from ovary. This is **ovulation**. The ovulated egg enters the oviduct where fertilization may occur.

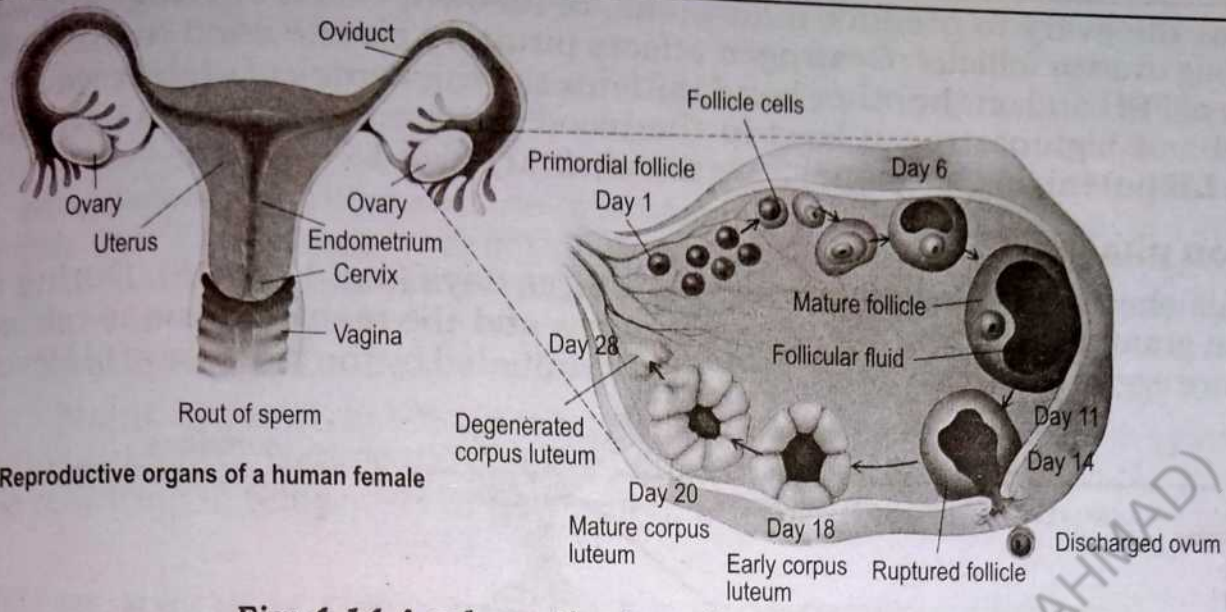


Fig: 4.14 A schematic view of a cross section through an ovary showing the various stages in the development of oocyte and follicle

Menstrual cycle:

This is correlated with certain uterine changes which occur to prepare it for a possible pregnancy; this ovarian cycle called **uterine cycle**. This monthly egg maturation and uterine preparation is collectively called **menstrual cycle** (often called **menses** - month). Menstruation begins around the age of thirteen and stops at menopause around the age of fifty.

Menstrual cycle prepares the uterus for a possible pregnancy.

The menstrual cycle is controlled by hormones and completes every 28 days. It occurs in four distinct phases (i) menstruation or 'M' phase (ii) follicle or 'F' phase (iii) ovulation or 'O' phase and (iv) corpus luteum or 'L' phase.

Menstruation phase:

Menstruation is the onsent of bleeding that is the discharge of blood and debris of discarded tissue of the uterus through vagina. Menstruation takes place when the body becomes aware chemically that no fertilization or pregnancy has occurred following the last ovulation. The progesterone secretion is stopped by corpus luteum and as a result, the soft spongy vascular internal lining of uterus called **endometrium** breaks off and starts flowing alongwith blood, out of vagina in the form of menstrual flow. The first day of menstrual flow is taken as the beginning of menstrual cycle. The stage lasts about five days and extends from day 1 to day 5.

Follicle phase:

This phase starts just after menstruation and ends with the release of ovum. It lasts about 07 days (day 6 to 12). This stage stimulates the development of many follicles in the ovary. Only one follicle, however, matures to produce an egg. This egg-producing follicle is sometimes called **graafian follicle**. The rest of the follicles do not develop and ultimately degenerate. This process is initiated by the **FSH** (Follicle Stimulating Hormone) secreted in blood from pituitary gland. FSH

stimulates the ovary to produce a hormone, of its own, called **oestrogen** from the degenerating ovarian follicles. Oestrogen affects pituitary on one hand to inhibit the secretion of FSH and on the other hand initiates the thickening of uterine wall. Low FSH level and high oestrogen level in the blood initiate the secretion of another hormone **LH** (lutenizing hormone) from the pituitary gland.

Ovulation phase:

This short phase lasts not more than three days (day 13 to 15). During this period the graafian follicle of the ovary ruptures and the mature ovum is released. This mature egg enters the oviduct. This stage is initiated by the increase of LH level.

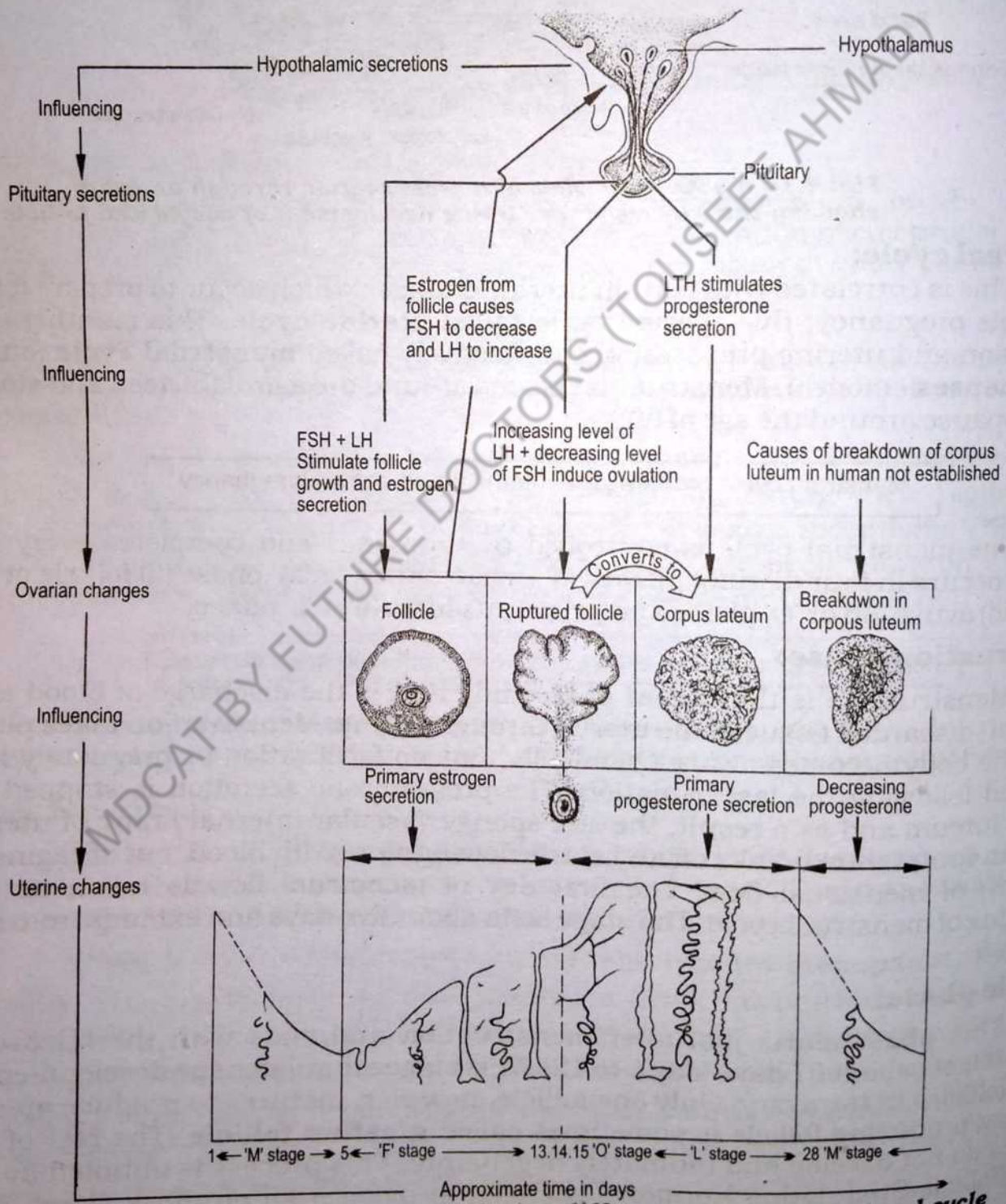


Fig: 4.15 The condition of endometrium during different stages of Menstrual cycle

Corpus luteum phase:

This phase is the longest period of menstrual cycle and lasts about 12-14 days (day 16 to 28). It is so called because LH causes the ruptured follicle to change into a yellowish body, the corpus luteum, which starts producing another hormone the **progesterone**. Progesterone maintains and enhances the growth of the mucous lining (endometrium) of the uterus. If the mature ovum, now in oviduct, is not fertilized the corpus luteum gradually degenerates, progesterone secretion stops and the internal lining of uterus disintegrates and sloughs off with blood, mensturation begins and the cycle starts again.

Malnutrition, ill health, mental strain and physical strains as in gymnasts and atheletes cause hormonic imbalance, which disturbs or even stops their menstrual cycle resulting in temporary or permanent infertility on part of these women.

4.14 HORMONAL CONTROL OF REPRODUCTIVE CYCLES

As studied earlier the reproductive cycle of human females are co-ordinated and timed by hormones. At puberty anterior lobe of pituitary gland under the influence of hypothalamus starts releasing **gonadotropin** hormones. These hormones are the follicle stimulating hormone (**FSH**) and luteinizing hormone (**LH**).FSH initiates follicle maturation and also stimulates the secretion of **oestrogen** from ovary. Oestrogen in addition to the development of secondary sexual characters also initiates the thickening of uterine endometrium and enhances the secretion of LH, which results in ovulation. As a result of ovulation a corpus luteum is formed and progesterone secretion starts. Progesterone prepares the uterus for pregnancy by making the endometrium more thick, spongy and vascular and ready for implantation of embryo. So between puberty and menopause the interaction of gonadotropins and sex hormones of ovary controls the female reproductive cycles.

> The hormonal system of a female is much more complex because she has the potential to develop a baby inside her body.

4.15 CONCEPTION AND PREGNANCY

In viviparous mammals like human beings the egg is fertilized by -a-sperm inside the body of the female and is retained there for further development. Fertilization in human being is more commonly called **conception** i.e., to conceive a baby. After fertilization has taken place in oviduct, the **zygote** begins to divide and forms a ball of cells called **blastocyst**, which travels down the oviduct and reaches the uterus to be embedded in its wall. This process is called **implantation** and it marks the start of **pregnancy**. The period starting from conception upto the birth of a baby is called **gestation** which lasts about 270 days in human beings.

Placenta:

The tissue attaching the embryo to the wall of uterus is called the **placenta**. The placenta looks like a flat pie shaped structure. It has millions of blood vessels that are the part of the embryo's blood system. Food and oxygen from the mother's

blood vessels through the placental blood vessels diffuse into the embryo. Carbon dioxide and wastes from the embryo diffuse out through the placenta into the mother's circulation. The blood of mother and the embryo, however, never mixes. Placenta also secretes progesterone hormone for maintaining pregnancy.

Amnion:

In reptiles, birds and mammals a clear extra embryonic membrane, the **amnion,** develops and surrounds the embryo. As its cavity becomes fluid filled it is called amnion sac or amniotic sac. The amniotic fluid keeps the embryo moist and by acting like a fluid cushion protects the embryo from any injury. Chorion and allantois are two other membranous sacs associated with most of the amniotic embryos. These membranes often called extra-embryonic coats protect the embryo and assist it in nutrition and excretion.

Umbilical cord:

A rope like structure formed from an extra-embryonic membrane the allantois, is called **umbilical cord**. It connects the embryo to placenta. The umbilical cord contains blood vessels, which carry food and oxygen from placenta to embryo and CO_2 and other wastes from embryo back to placenta. The umblical cord thus serves as a supply line between the embryo and its mother.

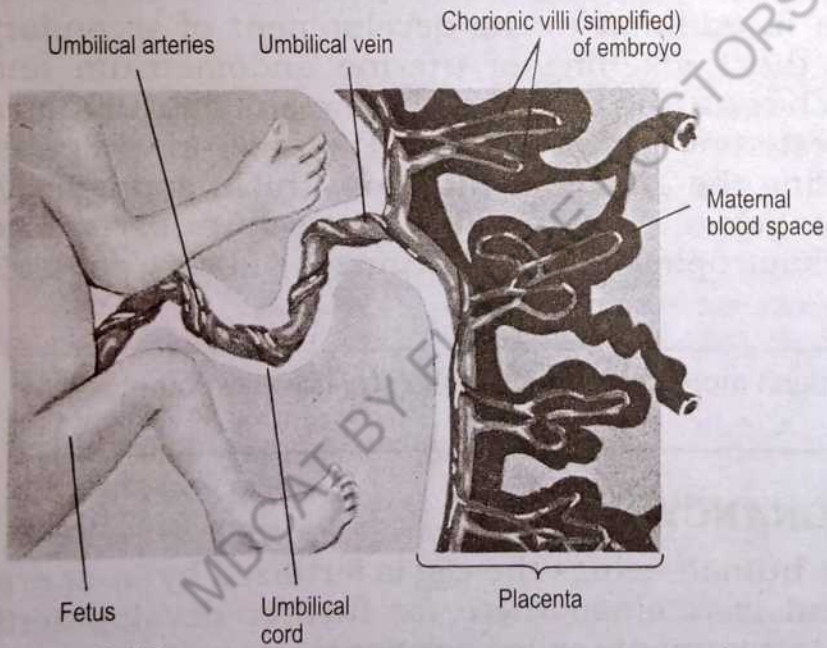


Fig: 4.16
Embryo, placenta and umbilical cord

Fig: 4.17 Embryo in the uterus enclosed in amniotic sac

4.16 BIRTH

After the gestation period, which in human beings, lasts about **nine months** from the time of conception till the baby is fully developed and ready to be born, the muscles of the uterus begin to contract and relax. These strong contractions of the muscles of the uterus, called **labour** are the result of increased secretion of **oxytocin** hormone from pituitary gland.

Lactation:

After the birth of the baby as soon as the umbilical cord is cut, food supply to the newborn is disconnected. It is now fed on a nutritious fluid the **milk** produced in the **mammary glands** of the mother. Though, throughout the pregnancy period under the influence of estrogen and progesterone the mammary glands go on developing but soon after the delivery, **prolactin hormone** of pituitary gland becomes active and triggers the mammary glands to start producing milk. A newborn baby knows how to suck and immediately starts suckling the milk. Release of milk from the breast is brought about by the contraction of its muscle under the influence of oxytocin hormone which is immediately secreted whenever a breast is stimulated by suckling of the baby.

4.17 TEST TUBE BABIES

Approximately 10 percent of the couples fail to have children. This condition, called **infertility**, may be due to a number of causes. In some females, however, this is due to the blockage of oviducts so that the sperms cannot reach the egg. This sort of infertility is overcome by a technique called **in vitro fertilization**. In this procedure some of the oocytes are sucked up from the ovary of that women before ovulation. These eggs are fertilized, outside her body in a laboratory dish, with the sperm taken from her husband. Eggs thus fertilized in vitro are allowed to develop for a few days in the laboratory and one is then transferred to her uterus for implantation where it undergoes normal development and is born the natural way.

4.18 SEXUALLY TRANSMITTED DISEASES

Sexually transmitted diseases is a group of ailments that may infect a healthy person during the sexual contact with an infected person. A few of these are discussed below.

1. Gonorrhea:

It is a disease caused by a bacterium *Neisseria gonorrhoeae*, which is introduced in the body through a sexual contact, usually through genitals and oral contact. The bacteria cause wounds in genital tubes and the infected males experience burning sensation during urination with discharge of thick white pus from urethra. In female infectees oviducts become damaged and blocked. If untreated it can cause infertility in both males and females. An infected mother can transmit these bacteria to her newborn baby while he or she is being delivered. These babies more often suffer eye infections and can become blind if not treated immediately.

2. Syphilis:

It is caused by a spirochaete bacterium *Treponema pallidum*. These bacteria not only damage the reproductive organs but also affect nervous system and skeletal system in addition to causing a large number of lesions. These conditions often become fatal not only to the infected men and women but also to their newborn babies. Prolonged antibiotic treatment is the probable remedy.

3. Genital herpes:

Genital herpes is characterized by painful blisters and ulcers on and around external genital organs. It is caused by a virus called *Herpes simplex*. Sexual partner or newborn baby receives this infection from body fluids or genital fluids. Use of antibiotics protect from the complications of this infection but the disease itself is not cured.

4. AIDS:

Acquired Immune Deficiency Syndrome is a fatal disease of the recent times caused by HIV (Human Immuno deficiency Virus). HIV infection destroys the patient's immune system and exposes infected person to all type of infections. Gential and other body fluids are the major source of infection. Unscreened blood transfusions or reuse of syringe needles are also important modes of its propagation. Newborns can also become infected through placenta of HIV infected mother. The vaccine for its cure is not yet available though research is on.

To reduce the chances of the infection of these dangerous STD (sexually transmitted diseases) both the husband and wife should restrict to each other. This is also in accordance with as per Quranic / Religious directions.

KEY POINTS

- Plants are characterized by an alternation of generations.
- Flowers develop from compressed shoots with four whorls of modified leaves separated by very short intenodes.
- The male gametophytes are sperm containing pollen grains which form within the chamber of anthers at the tips of stamens. The female gametophytes are egg containing structures called embryo sacs. Embryo sacs develop inside structures called ovules, which are enclosed by the ovaries (the bases of carpels).
- Dioecious (two houses) plants are analogous to the presence of testes and ovaries on separate male and female animals. Date palms are dioecious.
- Pollination occurs when pollen grains are released from anthers and carried by wind or animals on to the sticky stigmas at the tips of carpels.
- Double fertilization gives rise to the zygote and endosperm.
- Reproduction is the process of continuity of a species, generation after generation.
- Animals reproduce asexually as well as sexually.
- Cloning is a recent but special type of asexual process of reproduction which is still being worked upon.
- Sexual reproduction takes place by the fusion of male and female gametes.
- Gametogenesis is the process of gamete development. Formation of sperms is called spermatogenesis and those of eggs is oogenesis.

EXERCISE

1. Encircle the most correct choice:

i) Parthenogenesis is a type of reproduction which requires
a) One gamete b) Two gametes
c) Two-parent d) No parent

ii) A clone exactly resembles with
a) Mother b) Egg donor
c) Diploid nucleus donor d) None of these.

iii) Each primary oocyte ultimately develops into
a) One ovum b) Two ova
c) Three ova d) Four ova

iv) End of fertility in a human female is
a) Puberty b) Ovulation
c) Menopause d) Menses

v) Ovulation is initiated by (hormone)
a) FSH b) LH
c) Estrogen d) Progesterone

vi) Testes produce
a) Estrogen b) Progesterone
c) Testosterone d) Yolk sac

vii) which one of the following in endocrine gland?
a) Liver b) Spleen
c) Pancreas d) Ovary

viii) During pregnancy the production of ova is prevented by
A) Estrogen b) Progesterone
c) Prolactin d) None of these

ix) The hormone which stimulates release of egg is called
a) FSH b) LH
c) LTH d) None of these

x) Female gametophytes of pinus consists of
a) 2 Archegonia b) 2-5 Archegonia
c) 5 Archegonia d) No Archegonia

xi) Type of sexual reproduction in which fusing gametes are morphologically similar but physiologically dissimilar

a) Isogamy b) Anisogamy
c) Conjugation d) Oogamy

xii) The embryo of grass seed is enclosed by a sheath consisting of coleorhiza which covers the

a) Hycotyle b) Epicotyle
c) Root d) Shoot

xiii) A kind of inflorescence in which flowers are sessile and unisexual but not covered by spathe

a) Raceme b)Spike
c) Catkin d) Spadix

2. Write detailed answers of the following questions:

i) How male and female gametophytes of angiospermic plant develop?

ii) Give the structure and mode of germination of a dicot and monocot seeds.

iii) What is Asexual reproduction. Give various methods found in flowering plants.

iv) Differentiate between asexual and sexual reproduction. Describe any three of its methods in animals.

v) Describe with the help of simple diagrams the human reproductive organs.

vi) What is menstrual cycle? Discuss its various phases and the events taking place in each phase.

vii) What are sexually transmitted diseases? How do they usually spread?

viii) Describe human male and female reproductive organs with a suitable diagram.

ix) Describe the menstrual cycle.

3. Write short answers of the following questions :

i) What is a sporophyte?

ii) What do you mean by gametophyte?

iii) What do you mean by complete and incomplete flower?

iv) What is the meaning of perfect and imperfect flowers?

v) Explain the terms monoecious and dioecious plant.

vi) Explain double fertilization.

vii) Explain the term hypocotyle and epicolyte?

viii) What is gametogenesis? What are their types?

Ix) What are three necessities of sexual reproduction?

x) Why monozygotic twins have the same sex?

xi) What is genetic monotony ?

xii) Differentiate between spermatogenesis and oogenesis.

xiii) Why testes descends down in human male foetus before birth?

4. Define the following terms.

I)	Gestation	ii)	Apomixis
iii)	Heterogamy	iv)	Inflorescence
v)	Parthenocarpy	vi)	Photoperiodism
vii)	Parthenogenesis	viii)	Gametogenesis
Ix)	Oviparity	x)	Menopause

5. Dirstinguish between the following

i) Racemose and cymose inflorescence.

ii) Oviparity and viviparity

CHAPTER 5

GROWTH AND DEVELOPMENT

Every living organism after came into being as a single cell, the zygote, passes through the phases of growth or development in order to become an adult or mature form.

In biology the most amazing phenomenon is the development of new multicellular organism from one cell zygote. It is our common observation that, a zygote of mouse develop into mouse, an earth worm zygote into earth worm and a mango zygote into mango plant. Zygote is actually the foundation cell of a new organism. Thus a single celled zygote undergoes a series of progressive changes occur in the zygote after which it becomes a multicellular adult. These progressive changes, which occur during this period is called **development** or in other words we can say that development is "the study of a process of progressive changes through which a fertilized egg (in rare case unfertilized egg) passes before it assumes an adult form". The study of developmental changes is called **embryology** or **developmental biology.** The developing structure from zygote, which undergoes through these changes is called **embryo.** In animals, development results in an adult which resembles to its parent or a small premature free living larva. Whereas in plants development results in the formation of a seed which become a new plant as a result of another process called **germination**. When this miniature or small seedling comes into being a second phase of the life starts which is called **growth**.

Growth may be defined as "a permanent irreversible increase in size, weight, shape and structure usually accompanied by a permanent change of form". A new born becomes mature when it is passed through growth.

5.1 GROWTH AND DEVELOPMENT IN PLANT

In lower plants the entire plant body may be capable of growth. In the higher plants, however growth is confined to certain regions called the growing points. These regions are called **meristems.** They consist of group of cells, which are capable of division and giving rise to new cells. These dividing cells are called meristematic cells. The most important groups of meristematic cells are found at the stem and root apices and constitute the **apical meristem.** Their activity results in primary structure of a plant or the primary growth. They are responsible for the increase in the length of the plant's axis at both the stem and root branches. They are also responsible for the production of lateral appendages such as leaves and floral parts. In certain cases increase in length also takes place by the activity of **intercalary meristem**. These are parts of the apical meristem which have become separated from the apex by permanent tissues and left behind as the apical meristem moves on during growth. They occur at the base of internodes in many grasses, below the node in some mints and at the base of the leaf in many plants. Besides the apical and intercalary meristem, the gymnosperm and most dicots contain **lateral meristem** in the form of cylindrical sheaths in the vascular bundles or between them and beneath the epidermis. These are the cambium and phellogen of cork. Activity of these tissues result in the increase in diameter of stem and root and the secondary tissues of plants are formed. This increase in thickness due to activity of lateral meristems is called **secondary growth**.

The process of germination is also explain in Quranic Verses.

"Lo! Allah (it is) Who splitteth the grain of corn and the date-stone (for sprouting). He bringeth forth the living from the dead, and is the bringer-forth of the dead form the living. Such is Allah. How then are ye perverted?"

(Sura Al-An'am 6, Ayah 96)

"And he is Who hath produced you from a single being, and (hath given you) a habitation and a repository. We have detailed Our revelations for a people who have understanding."

(Sura Al-An'am 6, Ayah 99)

5.1.1 Phases of growth:

In lower plants (Bryophytes), growth simply involves the enlargement of cells followed by cell-division. In higher plants like angiosperms, increase in length takes place only at the apices of the roots and shoots, which can be recognized as three regions exhibiting three phases of growth.

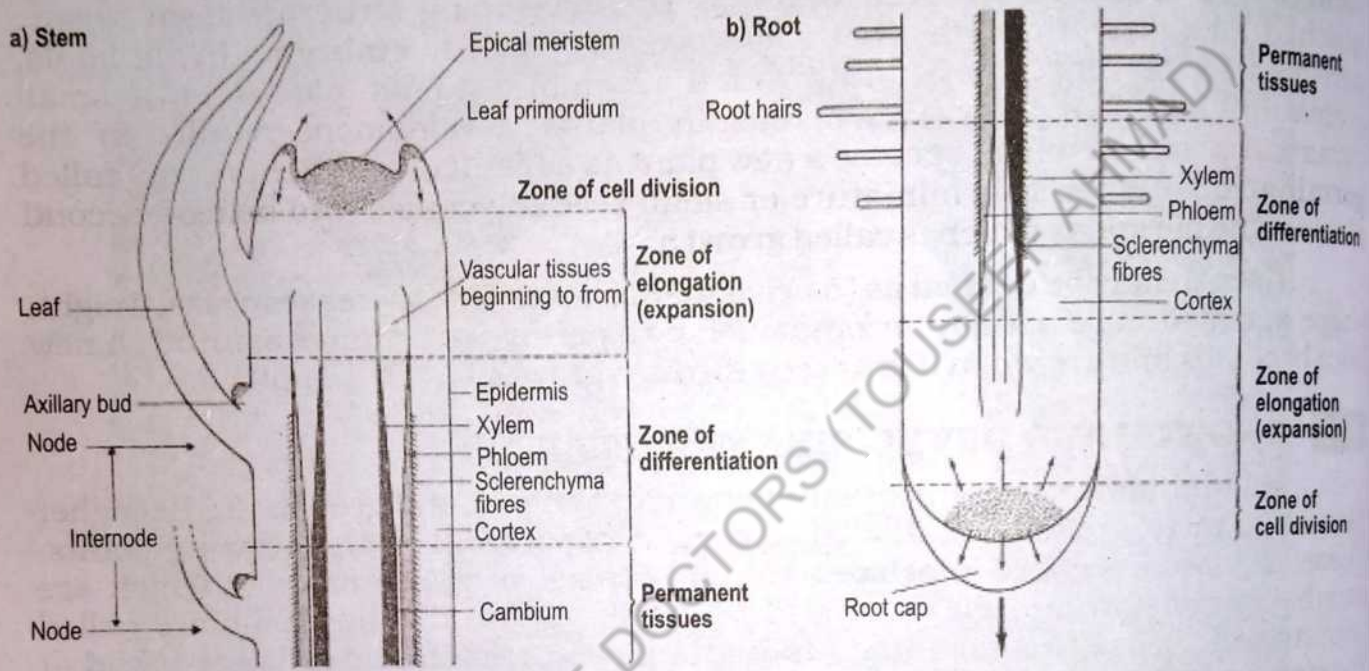


Fig: 5.1 Longitudinal section of stem and root apices showing primary growth and different growing zone in stem and root apices

1. The formative phase:

This is restricted to the tips of roots and shoots, where the cells constantly divide and thus increase in number. The cells in these formative regions are closely packed together. They have thin cellulose walls, dense cytoplasm and large nuclei.

2. Elongation phase:

This phase occurs immediately behind the formative region. The cells here do not divide, but on account of their turgid condition they enlarge and elongate until they reach their maximum size. In the root, the region of elongation extends over a few millimeters and in the stem over a few centimeters.

3. Maturation or differentiation phase:

This lies behind the region of elongation. Here the thickening of the cell-walls takes place. The enlarged and elongated cells are modified into permanent ones, Thus in the region of maturation the cells become adapted to perform different functions.

5.1.2 Secondary growth:

Apical or primary growth, as just described, increases the length of stems and roots. How then is their girth increased from year to year? This is achieved by a process of **secondary growth** in the permanent zone formed during maturation phase. Secondary growth may be defined as the increase in diameter of stem and root due to activity of secondary meristem, called **cambium.** Initially the cambium is restricted to a series of small groups of cells.

The first step in secondary growth involves the linking of these groups to form a ring of cambium tissue between the xylem and the phloem. This is achieved by radial divisions of the cambium cells. The xylem is situated on the inner side of the cambium ring and the phloem on the outer side. The cells of the cambium ring now divide tangentially to form secondary xylem tissues on the inside and secondary phloem on the outside. In between adjacent vascular bundles they form secondary parenchyma, there by increasing the girth of the medullary rays. In the stem similar columns of parenchyma are formed within the secondary xylem and phloem, forming secondary **medullary rays.**

5.2 CONDITIONS FOR GROWTH

Growth is brought about by cell-division, expansion and differentiation. Any factor that directly or indirectly affects these processes will influence the rate of growth. From study point of view, these factors can be external and internal. External factors include a whole host of environmental influences; temperature, light, nutrient, oxygen etc. On the other hand internal factors may be hormone, water, nutrition, vitamins etc.

5.2.1 External conditions which alter the rate of growth:

Following are the main external conditions which alter the rate of growth either positively or negatively.

i) Temperature:

Most the enzymes work optimumly in between 25°C to 37°C. Therefore, metabolic functions of cell, formation of new protoplasm and cell-division rapidly takes place in between the range of this temperature. Normally rate of growth increases with the increase in temperature. At very high temperature the rate of growth stops and plant may die due to excessive transpiration or loss of enzyme.

ii) Light:

Light is the very important condition for the plant growth. It is required for the synthesis and action of chlorophyll without which photosynthesis can not take place. Usually, light affects the rate of growth in three ways.

Intensity of light: It affects the synthesis of chlorophyll and other pigments. High intensity of light destroys the chlorophyll which ultimately affect the rate of photosynthesis. The quality of light also has influence on growth rate, such as red light favours elongation of cells and blue light enhances the cell division but retards cell enlargement. In the same way, ultraviolet light destroys the protoplasm and retards the growth.

Duration of light affects the growth of vegetative and reproductive structures e.g. photoperiodism in which light duration induces or suppresses the flowering.

iii) Oxygen:

Oxygen does not generally affect the growth of aerial parts of plants but it can have a profound influence on the growth of root(figure 5.2).

Indirectly the supply of O_2 is required for energy production by respiration. Without O_2 no metabolic activity is possible and no growth. A very high supply of oxygen however inhibit growth by photorespiration which is a wasteful process.

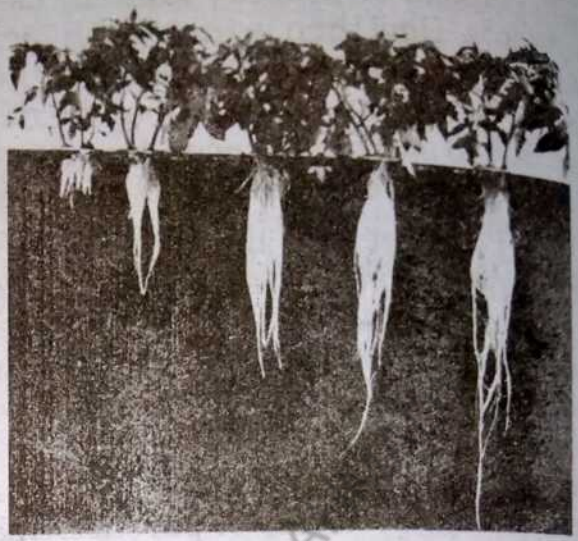


Fig: 5.2 Effect of oxygen concentration on the growth tomato root

iv) Carbon dioxide:

Carbon dioxide is necessary for photosynthesis and food production. If this process will continue, more food and other compounds for the synthesis of new protoplasm will be produced.

v) Nutrients:

Efficiency and deficiency of different nutrients play an important role in the growth e.g. plants growing in nitrogen deficient soil cannot manufacture enough protein and show stunted growth and development.

5.2.2 Internal factors:

Internal factors affecting growth include the relative quantities of different hormones present in the body and the genetic constitution of the organism. These two are connected in such a way that the genes influence growth through the intermediary of hormones. The hormones are also influenced by environmental factors. Plant hormones which affect the rate of growth are Auxin(Indole-acetic acid), Gibberellin and cytokinin. They are influenced by light, gravity, water etc. We have already discussed the role of hormones in previous chapters.

5.3 GROWTH CORRELATIONS

The growth of a plant organ is related with the growth of other organs which takes place in different directions, this reciprocal relationship is known as **correlation**.

Apical dominance is the most important correlation found in plant, It is our common observation that during growth of apical bud growth of lower axillary bud is suppressed. When apical bud is removed the growth of axillary bud is initiated. It means active growth of apices control the development of lateral buds. In other words, we can say that auxin is responsible for apical dominance and also responsible for inhibiting the growth of lateral bud. The inhibition of growth of

lateral bud is called **inhibitory effects.** The removal of apex releases the lateral buds from apical dominance is called **compensatory effects.** Cytokinin also play important role in apical dominance and in many cases if cytokinins is applied directly on the inhibited bud, it allows lateral buds to be released from apical dominance. In the same way in the presence of auxin other hormones like florigen, abscisic acid become suppressed. It is also observed that those plants that have dense growth have very little apical dominance.

5.4 GROWTH AND DEVELOPMENT IN ANIMALS

5.4.1 Process of development:

Animals begin their lives as single, diploid cells called **zygote**. How does this single cell zygote give rise millions of the cells of the adult body? why out of the millions contestants, only a single male gamete fuses with the ovum? How do the cells of the body differentiate into different tissues when all are descended from the same cell, the zygote? Such questions have challenged investigators for decades. These queries inspired the study of development. In a very broad sense, it is the study of the processes by which an animal proceeds from fertilized egg through adulthood and eventually leading to the death. However, in the proceeding discussion we shall consider early embryonic stages of chick; the process of aging, regeneration and some abnormalities in development.

Development of a zygote into adult involves a series of stages, which may varies in different animals, however the main stages are basically similar in all. A broad outline of the early stages of an animal's embryonic life can be represented as :

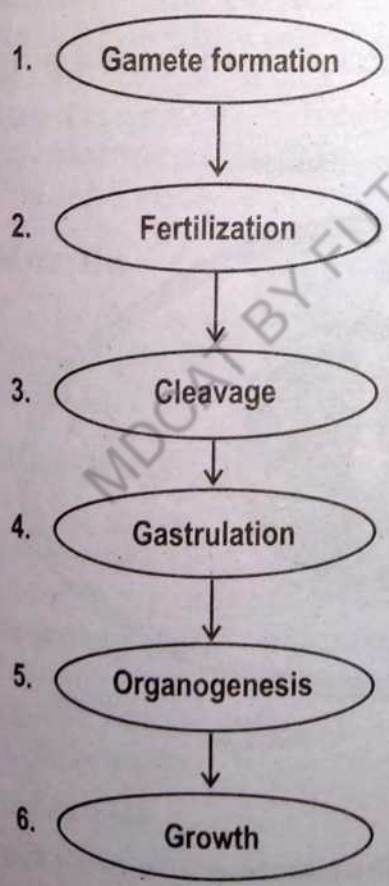


Fig: 5.3

1. Ova and sperms formation and maturation in female and male reproductive organs, respectively.
2. Sperm fuses and introduces its nucleus into the ovum. Both sperm and ovum nuclei fuse to form a single diploid nucleus.
3. Series of mitotic cell division, different daughter cells receive different regions of ovum's cytoplasm.
4. Cell divisions, migrations and rearrangements produce two or three primary tissues or germ layers.
5. Sub-populations of cells are sculpted into specialized organs and tissues.
6. Increase in the size of organs to attain maturity.

The steps involved in the development are irreversible and they occur in an ordered sequence one after the other. The life cycle of an animal can be seized at any stage by an inevitable process, the process of development as describe in the verse of the Holy Quran.

"Verily We created man from a product of wet earth. Then placed him as a drop (of seed) in a safe lodging. Then fashioned We the drop a clot, then fashioned We the clot a little lump, then fashioned We the little lump bones, then clothed the bones with flesh, and then produced it as another creation. So blessed be Allah, the Best of Creators! Then lo! after that ye surely die."

(Sura Al-Mo'minoon 23, Ayah 12-15)

"Who made all things good which He created, and He began the creation of man from clay. Then He made his seed from a drought of despised fluid. Then He fashioned him and breathed into him of His spirit; and appointed for you hearing and sight and hearts. Small thanks give ye!"

(Sura Al-Sajda 32, Ayah 7-9)

5.4.2 Development of chick:

In order to understand the patterns of development in vertebrates, we shall take chick as a model which shares most of the developmental patterns with other vertebrates.

Egg: The egg of a hen is polylecithal type. In this type of egg, enormous quantity of yolk is present. It is released from the ovary as **secondary oocyte** with a diameter of about 3cm. The protoplasm is restricted to a very small area called **blastodisc** or **germinal disc** towards the animal pole.

Fertilization : It is the process of fusion of sperm with the ovum to form a single diploid cell, the zygote. In hen, the fertilization is internal, i.e. it occurs inside the terminal part of the oviduct. The secondary oocyte, during fertilization undergoes second maturation division to become a mature ovum. It releases two polar bodies, which degenerate later on. The fertilized ovum, during its way through the oviduct, is covered by albumen outside its vitelline membranes. Out side the albumen, there are two shell membranes and hard, porous, proteinaceous calcareous shell. This fertilized egg is laid 24 hours after the fertilization.

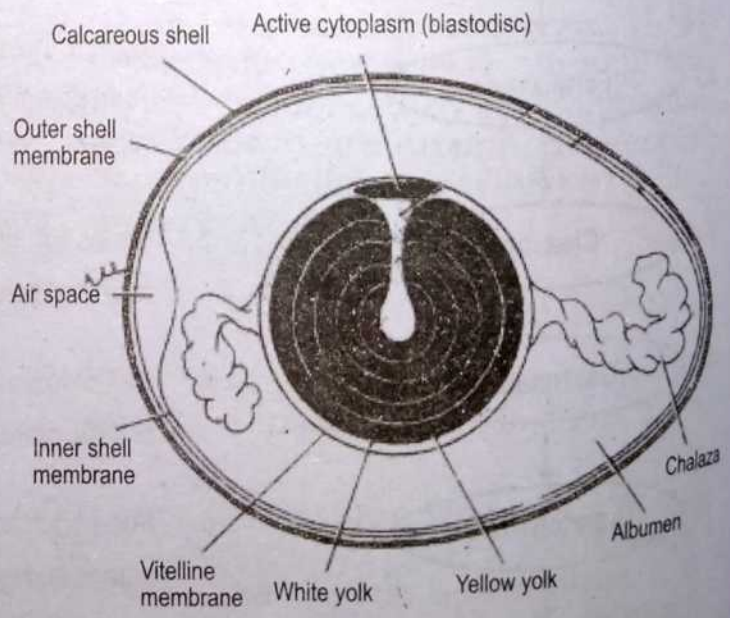


Fig: 5.4
Diagrammatic longitudinal section of a hen's egg

Incubation:

Further process of development requires the fertilized eggs to be kept at 36°C-38°C either naturally by the mother hen or artificially in incubator. At this temperature, the complete development of chick and finally its hatching takes place in twenty one days.

Cleavage:

It is a series of repeated mitotic divisions that takes place in the fertilized ovum. The cleavage in birds is restricted to the blastodisc lying on the top of the yolk towards the animal pole of the zygote, this type of cleavage is termed as **discoidal cleavage**. It does not divide the yolk of the ovum. In fish, reptiles and birds, the cleavage is **meroblastic type** or **incomplete** since it does divide the germinal disc completely, but not the whole egg. The first two cleavages occur at right angle to each other in vertical plane one after the other. The third cleavage occurs in horizontal plan parallel to the surface and as a result 8 blastomeres are formed. The rest of the cleavages are irregular and completely delimited cells are formed all over the germinal disc which is termed as **blastoderm**. This out come of cleavage called **cytoplasmic localization** helps seal the developmental fate of each cell's descendants.

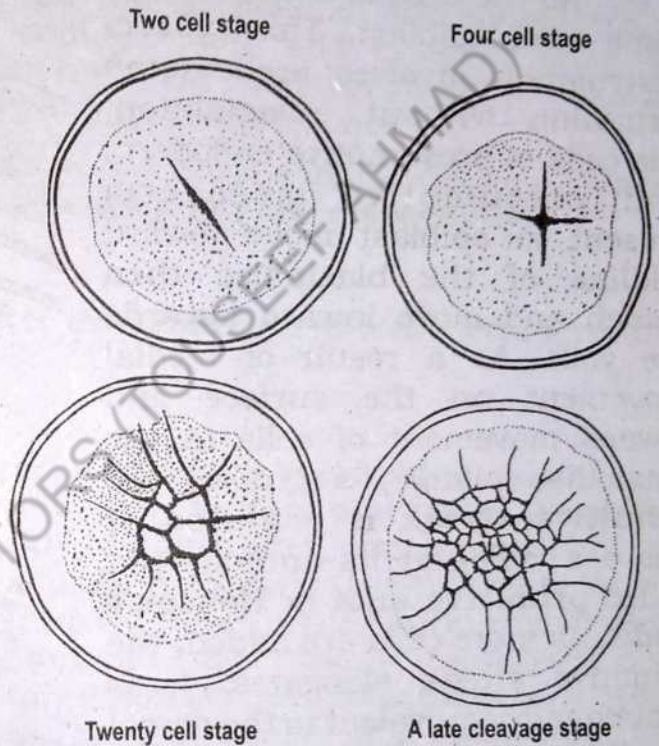


Fig: 5.5 Surface view of germinal disc of hen's egg showing early cleavage.

Morula :

As a consequence of cleavage, the embryo becomes a rounded mass of closely packed blastomeres, which resembles a mulberry and therefore is called **Morula**. It is a very short lived stage so changes into the next stage called blastula.

Blastula :

It is the embryonic stage which contains a fluid-filled cavity, the **segmentation cavity** or the **blastocoel.** In chick, it appears when the blastodermal cells split into two layers, the upper of **epiblast** and the lower layer **hypoblast**. In between these layers , the blastocoel appears. The marginal cells of blastoderm lie unseparated from the yolk and form the zone of junction or **area opaca**, while the central region is termed as **area pellucida**. The egg is laid almost at this stage.

Gastrula :

The next stage followed by blastula is called gastrula and the process of its

formation is called gastrulation. During this process, besides cell division, cell migration and their rearrangement at definite locations in the embryo occur. These cells begin to differentiate into definite layers, the ectoderm, the mesoderm and the endoderm.

All the cells of avian embryo come from epiblast. This type of gastrulation involves archenteron formation without invagination. The cells of presumptive endoderm and presumptive mesoderm present in epiblast move toward midline of the blastodisc then detach and move inward towards the yolk. As a result of medial movement on the surface and inward movement of cells at the blastodisc middle, a groove, the **primitive streak** is produced. It has a swelling at its anterior end called **primitive knot** or **Hensen's node**. As more cells are added, the primitive streak elongates. It is functionally equivalent to the dorsal lip of blastopore in frog.

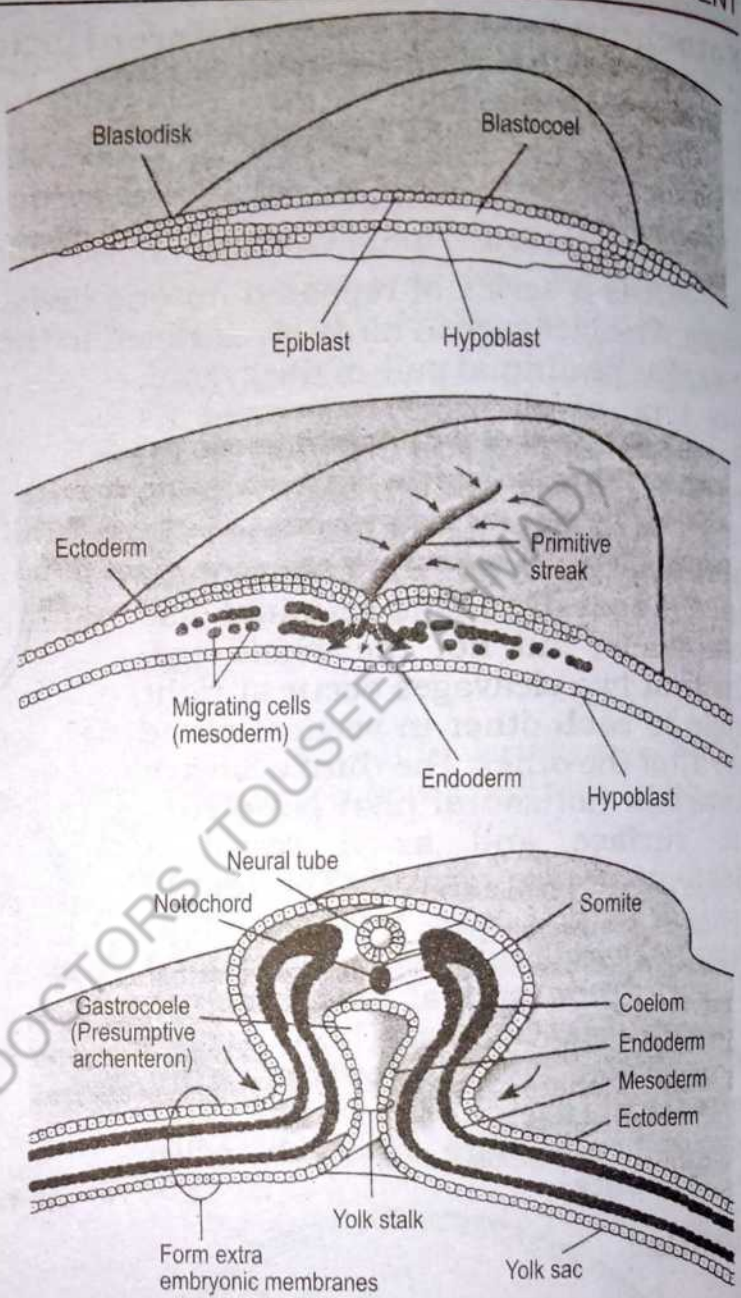


Fig: 5.6
Cleavage and gastrulation in a chick embryo

Endoderm formation :

Some cells of epiblast migrate through the primitive streak to move down ward mingling with cells of hypoblast, which contributes no cells to the embryo. It seems to help direct the formation of primitive streak and is required for the normal development. Eventually, segregating from the endoderm, the hypoblast cells form portion of a sac surrounding the yolk and a stalk connecting the yolk mass to the embryo.

Mesoderm formation :

As soon as the endoderm establishes, the remaining cells of the primitive streak begin to migrate laterally into the blastocoele to form a new layer of cells, mesoderm.

Notochord formation and differentiation of Mesoderm:

After the formation of primitive streak, the cells of the primitive knot migrate forward into the sub-germinal cavity to form a rod of cells, called notochord, which lies below the neural plate.

The mesoderm on each side of the notochord and nerve cord differentiates into three regions; epimere, mesomere and hypomere. The epimeres break up longitudinally into metamerically arranged segments on somites which later give rise muscles, axial skeleton and connective tissues.

About 24 hours of incubation, the lateral plate of the mesoderm is differentiated into an outer layer-the somatic layer and in inner layer-the splanchnic layer. The space formed in between these two layers is called **coelom**, which soon divides into embryonic and extra-embryonic regions.

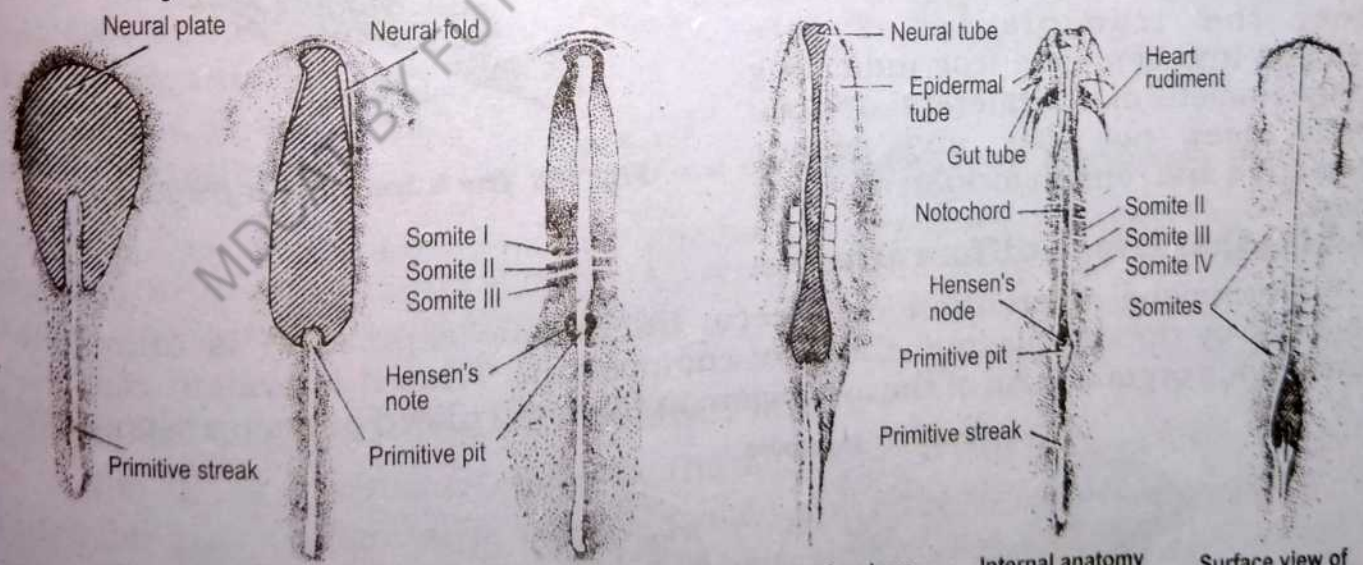
Later, the somatic layer fuses with the ectoderm and the splanchnic layer with endoderm to form **somatoplure** and **splanchnopleure**, respectively.

Ectoderm formation :

The remaining cells of epiblast after the migration of mesoderm form the surface layer or the ectoderm.

Neurulation:

During the formation of notochord, some of the ectodermal cells of area pellucida lying above the notochord divide rapidly to form a neural plate on the dorsal surface of the gastrula. It takes about 18 hours after incubation of the egg. As the cells divide continuously, the neural plate sinks inside the embryo to form a neural groove along the mid-dorsal line. Both the edges of the neural groove move towards each other and fuse together to form a neural tube. The embryo is now termed as neurula and the process of its formation is called **neurulation**. It takes about 24 hours after incubation of the egg. The neural tube later gives rise to the nervous system.



Embryo containing primitive streak, neural plate and epidermis (stage 5)

Antero-posterior extension of the neural plate formation of neural force

Internal anatomy of embryo of stages 7 to 8

Surface of embryo of 3 to 4 pair somite stage 8, 26 to 28 hr of incubation

Internal anatomy of stage 8 embryo

Surface view of embryo of 9 to 10 pairs somite stage

Fig: 5.7 Neurulation of chick

5.5 CELL DIFFERENTIATION AND ITS MECHANISM

The study of the process of development has clearly indicated that all the cells of embryo arise from the same fertilized ovum, so all of them have same number and kind of genes. However, from the process of gastrulation and onward some of the genes are activated and others are switched off, some even for ever. The process of selection of activation of some genes by a cell, (which are not activated by other cells of the embryo) is called cell differentiation. Once activated or inactivated in embryonic cells, usually those genes remain active or inactive in the descendents of the embryonic cells, for instance only the immature RBCs use the genes for the haemoglobin synthesis. A number of experiments indicated that cells even after being differentiated, do not lose any of their genetic information. For instance, in an experiment, **John Gurdon** removed the nucleus from the unfertilized egg of frog. Then he obtained nucleus from intestinal cell of a tadpole of the same species and implanted it into the enucleated egg. Surprisingly in some cases, the transplanted zygote developed into complete frog indicating that the nucleus of the differentiated cell usually does not lose any genetic information and remain totipotent.

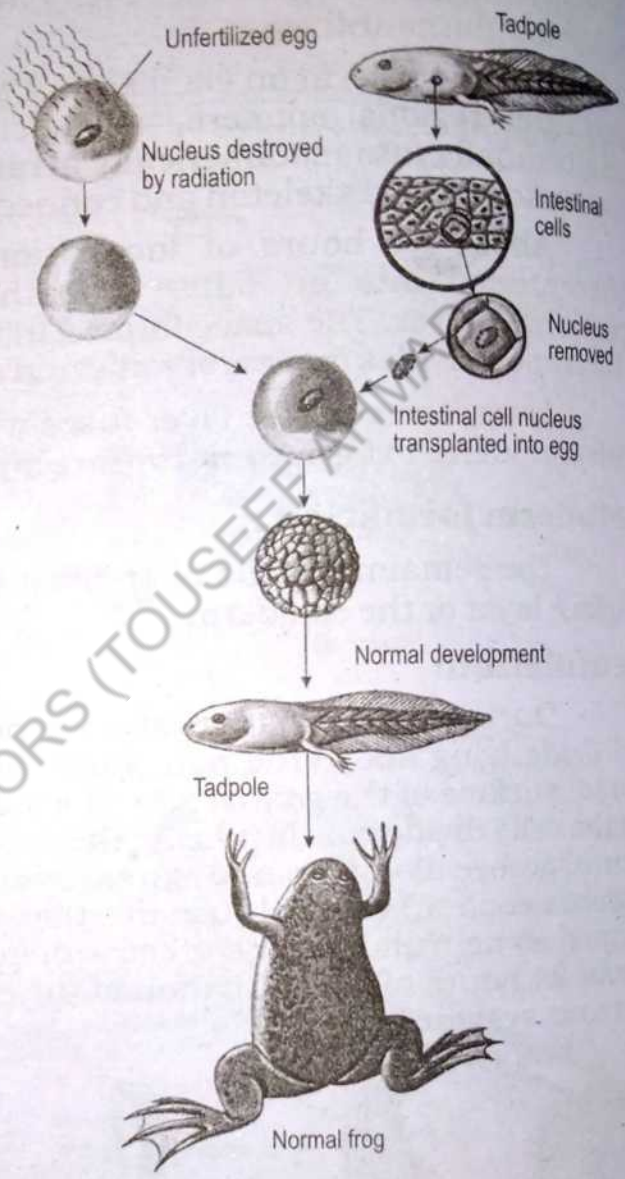


Fig: 5.8 The haploid of a frog's egg

5.5.1 Mechanism of differentiation

During the differentiation process, the genetic expression is ultimately influenced by the cytoplasmic chemical composition. Thus it is evident that the heterogenous organization of the cytoplasm in the unfertilized ovum is responsible

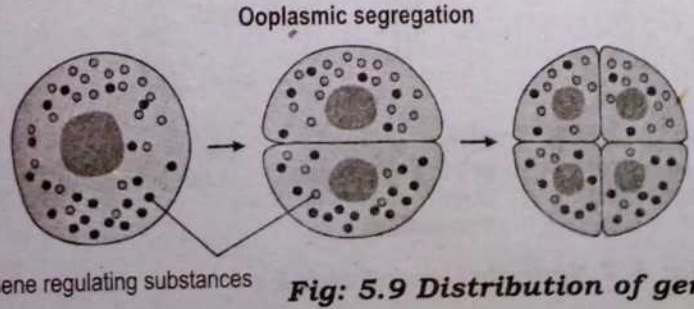


Fig: 5.9 Distribution of gene regulating substances

for later differentiation of embryonic cells into tissues. The process of cleavage, during the development divides the ovum's cytoplasm into compartments or cells containing necessary determinants (mRNA, proteins and other molecules) for the future differentiation of cells into tissues.

5.5.2 Embryonic induction and its mechanism:

Hans Spemann, a classical embryologist who received Nobel Prize in 1935 and his colleague **Hilde Mangold** in 1924 performed an experiment on embryonic induction. They cut the presumptive nervous system tissue just above the notochord and transplanted into the belly region of the embryo. They found that neural tissue failed to develop at the ectopic site.

In another experiment, they cut away the presumptive notochord tissue and grafted it under the presumptive belly ectoderm. Surprisingly, the belly ectoderm developed into the neural tissue.

From these experiments, they concluded that an embryonic tissue influences upon the other embryonic tissue through transmitting some chemical stimulus, the **primary organizer.** This phenomenon is called as **embryonic induction.**

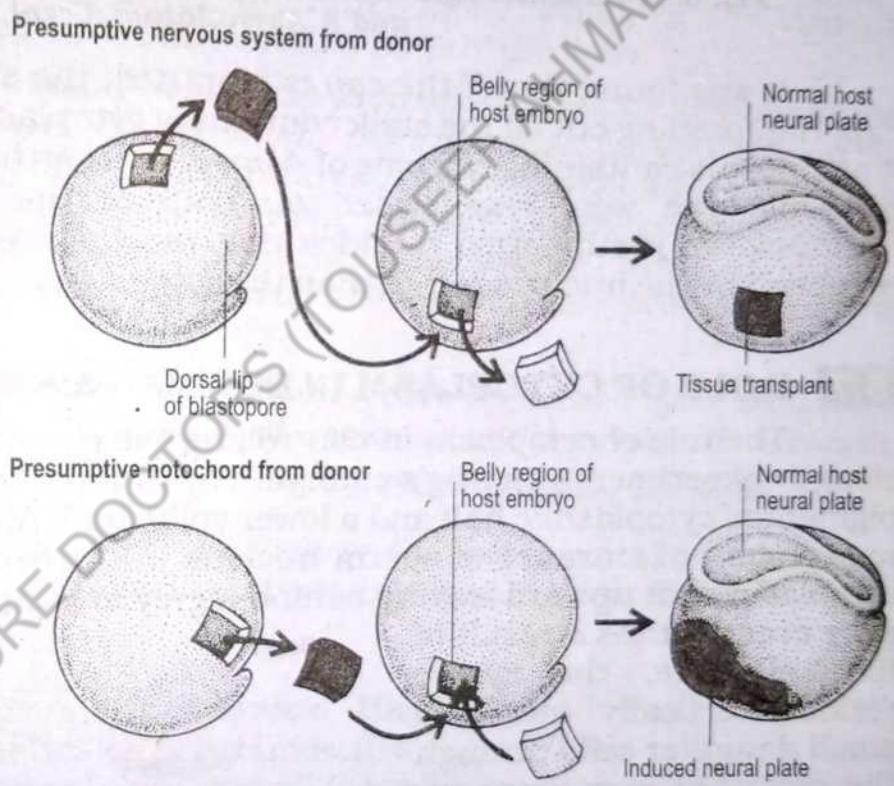


Fig: 5.10
Experiment performed by Hans spemann in 1924

Yet, the exact nature of the Spemann's organizer had not been clear. However, the developmental Biologists have discovered that some peptide growth factors seem to play the role of organizers.

5.6 ROLE OF NUCLEUS IN DEVELOPMENT

The role of nucleus in regulating the activities of cytoplasm was studied in a unicellular alga Acetabularia, which consists of rhizoid for its attachment to the ground and a cytoplasmic stalk with a disc like cap at its terminal end. On the basis of cap two species of Acetabularia, *A. mediterranea* having disc shaped cap with scalloped edges and A. *crenulata* with cap dissected into nearly separate lobes were identified.

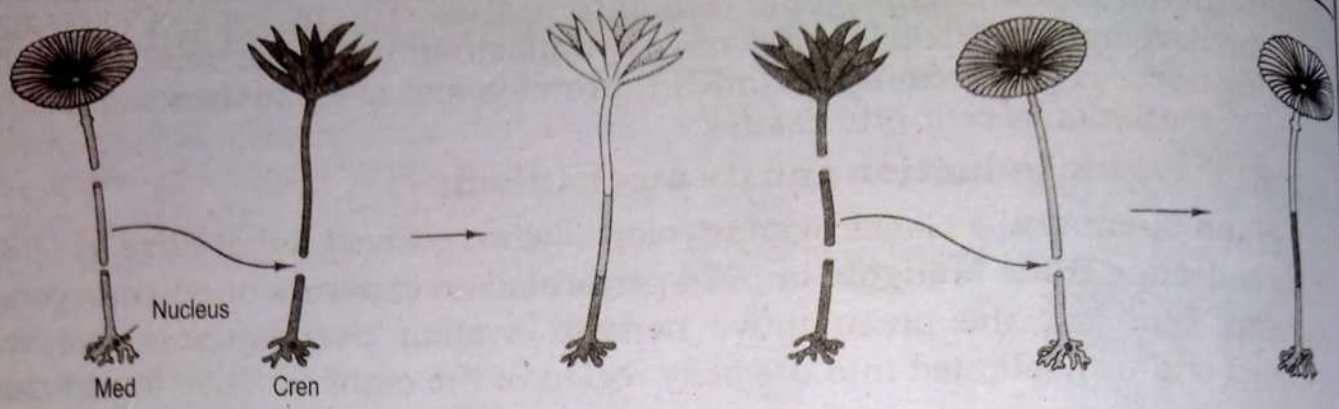


Fig: 5.11 Hammerling's experiments on Acetabularia mediterranea (med) and A. Crenulatam (Cren)

It was found that if the cap is amputed, the stalk would regenerate a new cap. Hammerling cut off the stalk containing cytoplasm of A. *crenulata* and grafted it on nucleus containing rhizome of *A. mediterranea* and vice versa. The caps of the previous type were regenerated on both of the grafted stalked species of *Acetabularia*. It supported the idea that the process of development of cap was regulated by the nucleus rather than the cytoplasm.

5.7 ROLE OF CYTOPLASM IN DEVELOPMENT

The role of cytoplasm in controlling the process of development was made clear by experiments on frog's embryo. The unfertilized ovum of frog has an upper pigmented cytoplasmic half and a lower yolky half. After fertilization, just opposite to the point of entrance of sperm nucleus in the ovum, some of the pigments of cytoplasm shift upward leaving behind a grey area in the form of a crescent called **gray crescent**. As a result of first cleavage, the zygote divides vertically into two small daughter cells through the center of grey crescent. Thus each daughter cell receives half of the crescent. If the two daughter cells are carefully separated from each other, so each of them develops into a normal tadpole larva. In an experiment, Hans spemann (1930) misguided the normal plane of first cleavage so one of the two daughter cells received entire crescent while the other non crescent.

Both of the daughter cells were separated and allowed to develop. The cell

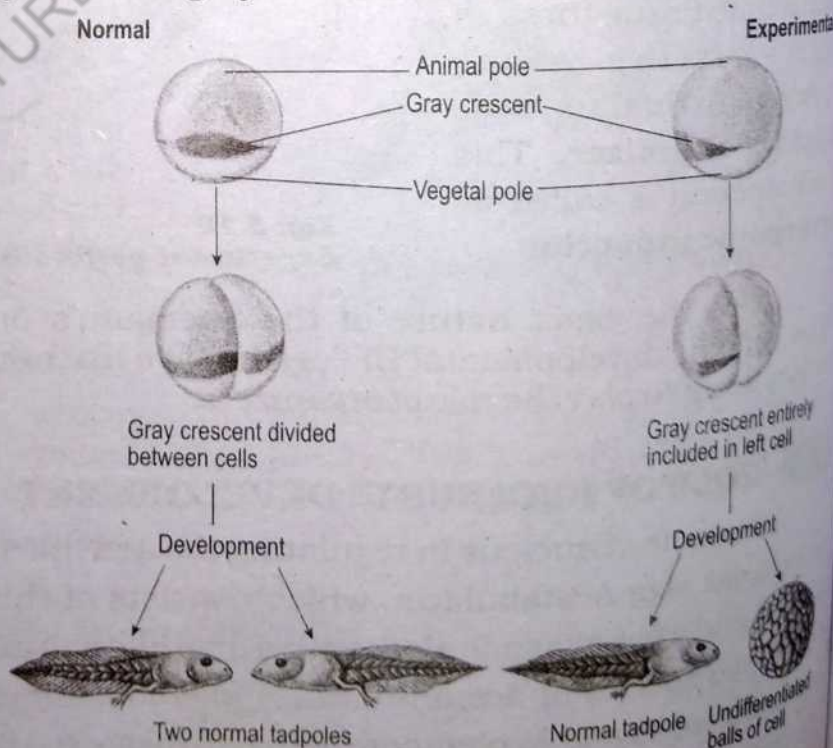


Fig: 5.12 Distribution of gene regulating substances during cleavage

with grey crescent developed into a tadpole while the other turned into a mass of cells and died. From this experiment it can be concluded that although both daughter cells were having identical genes, the cytoplasm of both was different. It supports the idea that cytoplasm containing grey crescent is required for the normal development of frog. Thus it proves that the cytoplasm do has some regulatory effects on the expression of genes.

5.8 AGING

It is a matter of fact that the body of multicellular animals undergo the process of progressive deterioration called aging. The science of aging known as **Gerontology** has gained a lot of interest in these days. In the process of aging the cells start to break down structurally and functionally, which lead to structural changes and ultimately the loss of different functions of the body.

In humans, people usually determine each others ages by identifying signs of aging such as loss of hair pigmentation, skin wrinkles particularly on face, development of small pigmented areas in the skin particularly on the face, general weakness, increase fat deposition, poor vision, gradual loss of memory, increased susceptibility to diseases, development of degenerative diseases such as osteoporosis, arthritis, etc. The Holy Quran also explain this process in his own words that:

"Allah is He Who shaped you out of weakness, then appointed after weakness strength, then, after strength, appointed weakness and grey hair. He createth what He will. He is the Knower, the Mighty." ***(Sura Al-Room 30, Ayah 54)***

Despite lot of advancements in Biology the exact cause of aging is yet unknown. However there are following interesting lines to think about.

1. Genetic origin:

Experiments conducted by **Leonard Hayflick** and **Paul Moor Head** indicated that we are genetically programmed to age. They cultured normal embryonic human cells. It was found that all the cell lines proceeded to divide fifty times, then stopped and then entire population died off. It implies that normal cells have a limited potential of division.

2. Gene mutations:

During the passage of time due to the accumulation of gene mutations, the capacity of self repair of DNA during its replication is lost. Thus the DNA is attacked and gradually denatured by some free radicals. This results in progressively inadequately functioning cells that cause the aging.

It is observed that low-fat diet, aerobic, low-impact exercises may likely to reduce some effects of aging.

Superoxide dimutase and catalase, two of the enzymes that facilitate the metabolic reactions much faster than their spontaneous rate, seem to help keeping you grow old before time. They are involved in breaking the $H_2O_2^{--}$ a toxic metabolic byproduct, as well as eliminate free radical O_2^-. In elderly people, the capacity to produce superoxide dimutase and catalase become defective.

5.9 REGENERATION

It is the ability of a living organism to reconstruct its lost parts of the body. Almost all embryos of animals have this capability. However, some animals retain this power after maturity and adulthood while others lose it. It is much more common in invertebrates than vertebrates. Generally speaking simpler animals have greater regeneration power than the advance ones. For instance, sponges have great power of regeneration. An adult hydra or star-fish if chopped into many parts, each part can regenerate into complete organism. Among arthropods usually appendages can be regenerated. Salamanders and lizards can regenerate their tails. In birds and mammals regeneration is mostly limited to the small wounds by the formation of a new tissue, **scar**. It seems that the regeneration potential is inversely related to the differentiation of cells. Thus the greater the differentiation among the cells of the body, the lesser will be regeneration.

5.10 ABNORMAL DEVELOPMENT

Deviations in the normal structure and functions of an organisms occur under unfavourable conditions during the embryological development and are called **abnormal development**. The study of such abnormalities is called **teratology.**

Although, the embryological development of an organism is a precisely controlled orderly sequence phenomenon, sometimes due to mutations, UV radiation, some drugs during the pregnancy, abnormal secretory functions of some glands, etc some kind of structural or biochemical abnormalities, which may be lethal, develop in the new individual. For instance, in man, some of abnormal conditions are listed as follow:

Disorders	Major signs and symptoms
Microcephaly	Individual with small skull in proportion to the normal body size.
Cleft lip and Palate	Split in upper lip and gap in the roof of mouth.
Polydactyly	Excessive number of fingers or toes.
Dextrocardia	Heart toward the right side of the chest.
Sickle cell Anemia	Abnormal sickle shaped RBC.
Turner's Syndrome	Female sexual defect.
Klinefelter's syndrome	Male sexual defect
Down's syndrome	Mental and physical retardation.
Haemophilia	Decreased ability or inability of the blood to clot.
Thalassemia	Fragile RBC cause hemolytic anemia.

KEY POINTS

- The progressive changes that occur in the zygote to become an adult called development.
- The study of developmental changes called embryology or developmental biology.
- Growing regions of plant are called meristem, if present at stem or root apex called apical meristem.
- The part of apical meristem which become separated from apex by permanent tissues called Intercalary meristem.
- In growing stem or root three regions are present which exhibit three phases of growth i.e. formative phase, elongation phase and differentiation phase.
- Study of embryonic stages is called Embryology.
- Development involves formation and fusion of gametes, formation of zygote, cleavage, morula, blastula, gastrula, and organogenesis.
- The egg of bird is polylecithal type.
- In chick the cleavage is irregular and discoidal type.
- The outcome of cleavages is cytoplasmic localization.
- Blastula contains blastocoel.
- The differentiation of cells of embryo is regulated by the cytoplasmic determinants.
- Embryonic induction involves an embryonic tissue influence upon other embryonic tissue through chemical stimulus.
- Process of progressive deterioration in the normal structure and function of tissue is called aging.
- Regeneration is the reconstruction of the lost parts of the body.

EXERCISE

1. Encircle the most correct choice:

i) In bryophytes growth takes place at
a) apices b) lateral region
c) through out the body d) All are correct

ii) Cells which are capable of cell-division are
a) mature cell b) meristematic cell
c) permanent cell d) parenchyma

iii) Intercalary meristem may occur at
a) base of internodes b) below the node
c) both a and b d) none of them

iv) Secondary growth is caused due to activity of
a) cambium b) phellogen of cork
c) both a and b d) none of them.

v) The egg of chick is laid at this stage.
a) cleavage b) morula
c) blastula d) gastrula.

vi) Cytoplasmic localization is a consequence of :
a) fertilization b) cleavage
c) morula d) blastula.

vii) The blastoderm splits into
a) epimere and hypomere b)mesomere and epimere
c) epimere and mesomere d) epiblast and hypolast

viii) The phenomenon in which one embryonic tissue influences upon the other is
a) gastrulation b) embryonic induction
c) neurulation d) cleavage.

ix) Nerve cord is formed by
a) ectoderm b) mesoderm
c) endoderm d) all of these

x) Notochord develops from
a) ectoderm b) mesoderm
c) endoderm d) none of them

xi) Kidney develops from
a) epimere b) mesomere
c) hypomere d) all of these

xii) Which of the following is correct order
a) morula-cleavage-blastula b) blastula-gastrula-morula
c) cleavage-morula-blastula d) neurula-morula-blastula

2. Write detailed answers of the following questions:

i) What is apical growth? Describe the phase of apical growth.

ii) Describe the external factor which influence the rate of growth in plants?

iii) What do you mean by growth correlation? Explain it with the help of examples?

iv) What is gastrula? Explain the formation of three germ layers in gastrula of chick.

v) Explain mechanism of cell differentiation and embryonic induction in chick embryo.

vi) Discuss the role of nucleus and cytoplasm in development.

vii) What is Gerontology? Explain the possible reasons of aging?

3. Write short answers of the following questions :

i) How many ways the light influences the rate of growth?

ii) Do the cells beneath the formative phase differ from each other?

iii) Why growth is different from development?

iv) What are Primary oocyte and secondary oocyte?

v) What is the importance of cleavage in development?

vi) Distinguish between blastula and gastrula.

vii) What are cell differentiation and embryonic induction?

viii) What is aging?

ix) What is abnormal development?

x) Cleavage is chick is called discoidal type, why?

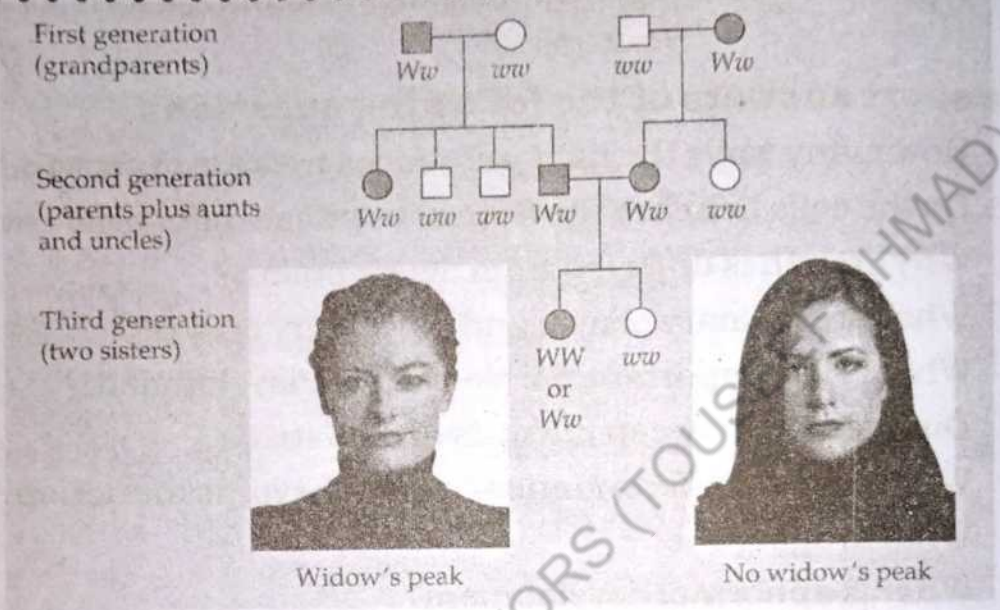
xi) What is meant y by meroblastic cleavage?

xii) What is cytoplasmic localization?

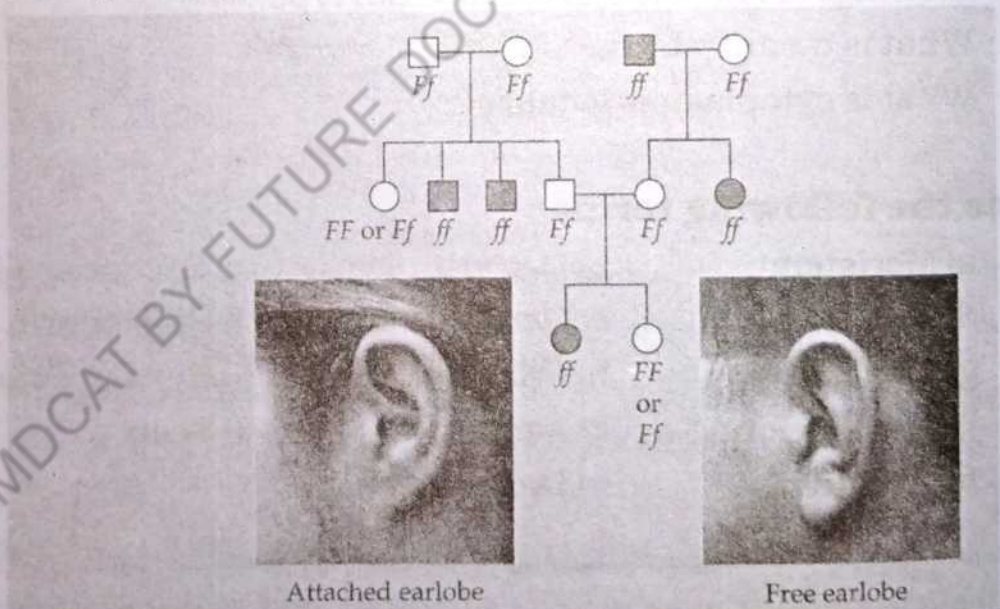
4. Define the following terms :

a) Meristem
b) Growth
c) Secondary growth
d) Zygote
e) Germinal disc
f) Blastoderm
g) Cleavage
h) Primitive streak
i) Hensen's node
j) Neurulation
k) Aging
l) Scar
m) Teratology
n) Dextrocardia

CONTINUITY OF LIFE



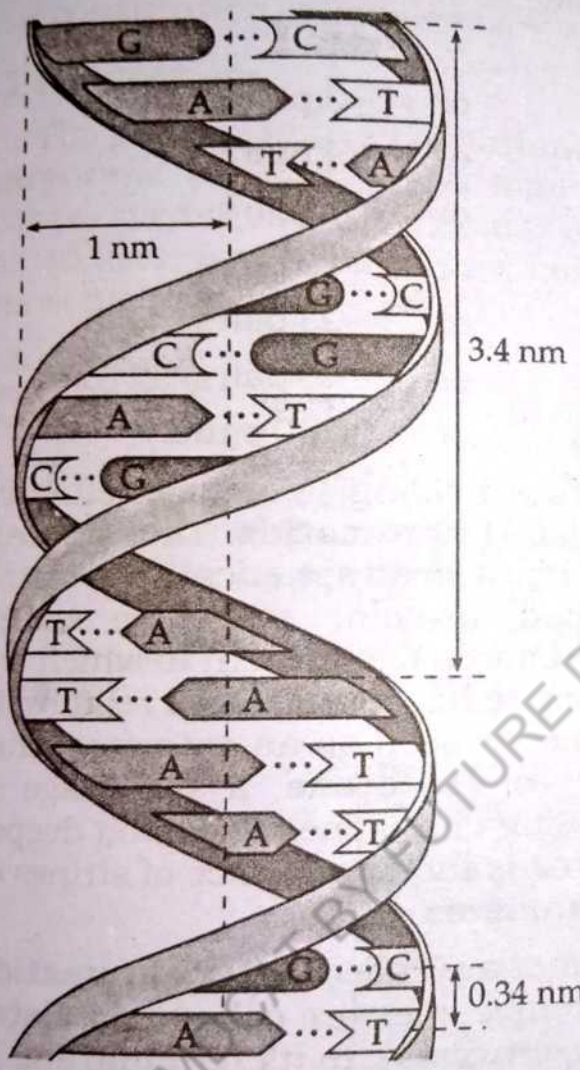
(a) Pedigree tracing a dominant trait (widow's peak)

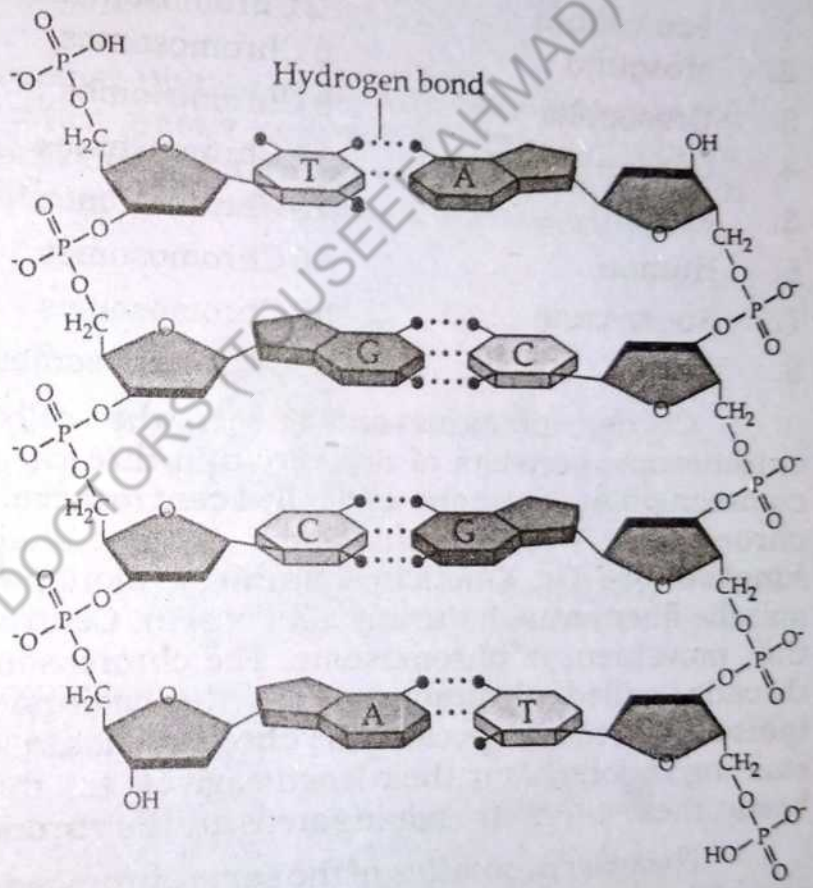


A fertilized egg formed by the fusion of single cell from each parent develops into a new individual and so the parents are survived by their offsprings. How does it happen? A zygote receives from its parents a complete set of biological computer chips, the chromosomes, lodged in its nucleus. Chromosomes contain the entire genetic information stored in the blue print of life, the DNA, which not only develops and maintains an animals but also transfer its command to the next generations.

CHAPTER 6

CHROMOSOMES AND DNA





In 1953, James Watson and Francis Crick won a race to discover the three-dimensional molecular structure of deoxyribonucleic acid(DNA). DNA is the most celebrated molecule of our time, for it is the substance of inheritance. Mendel's heritable factors and Morgan's genes on chromosomes are in fact, composed of DNA. Chemically speaking your genetic endowment is the DNA you inherited from your parents.

The term chromosome (Gr. Chroma = Coloured, Soma = Body) is misnomer because chromosomes are not coloured bodies. They have been named so by the German embryologist **Walter Fleming** (1882) while examining rapidly dividing cells of salamander larvae after treating with **Perkin's Aniline** dyes observed that chromosomes colour is much darker than the rest of the organelles.

Chromosomes may be described as thread like structures present inside the nucleus, bearer of hereditary characters in the form of **genes**; present in pairs in an individual and their number remains constant from generation to generation in a given species.

The chromosomes number however varies from species to species and ranges from single to hundreds pairs as given below.

1.	Penicillium	:	2 Chromosomes		
2.	Mosquito	:	6 Chromosomes	or	3 pairs.
3.	Drosophila	:	8 Chromosomes	or	4 pairs.
4.	Garden pea	:	14 Chromosomes	or	7 pairs.
5.	Frog	:	26 Chromosomes	or	13 pairs.
6.	Human	:	46 Chromosomes	or	23 pairs.
7.	Sugar-cane	:	80 Chromosomes	or	40 pairs.
8.	Fern	:	1000 Chromosomes	or	500 pairs.

Chromosomes can only be seen when cells are dividing. In mature cell, each chromosome consists of two very thin threads called **chromatids**. They share a common point of attachment called **centromere**. It is a small spherical zone on the chromosome. Within centromere a disc-shaped protein, structure called **kinetochore** (Gr, Kinetichos, putting in motion + chorous) is present to which the spindle fibers attach during cell-division. Centromere has a functional relation to the movement of chromosome. The chromosome is seen as an extremely thin threads, called **chromonema**, at the beginning of **leptotene**, a sub stage of **meiosis**. In many species, the **chromonemata** (Sing-chromonema) exhibit deeper staining regions along their lengths, giving the threads the appearance of strings of beads, these intensely staining areas are the **chromomeres**.

The two chromatids of the same chromosomes are called **sister chromatids** and chromatids of two different homologous chromosomes are called **non sister chromatids**. The length of a chromosome from centromere to its terminal end is called **arm** of the chromosome.

6.1 TYPES OF CHROMOSOMES

Recall that according to the position of centromere, there are four types of chromosomes i.e. **metacentric**, **sub-metacentric**, **telocentric** and **acrocentric** as described in chapter 4 of class xi.

Homologous chromosomes:

Chromosomes in an individual appear in a paired sets, one set is received from male and the other from the female parent. Such paired sets, the homologous pairs contain both morphologically similar members with same set of genes.

Autosomes and sex-chromosomes:

Chromosomes, which are similar in males and females of same species are called **autosomes** and the chromosomes, which are different in them are called **sex-chromosomes**. Nomally each individual possesses a pair of sex chromosomes, which are designated as X and Y. The male possesses XY and female possesses XX chromosomes but in some animals the position is reversed e.g. moths, birds and some fishes.

In them it is the female which possesses a pair of unlike chromosomes where as male has like chromosome. To avoid the confusion, the sex chromosome in such animals is called Z instead of X and the other member is called W. Thus the genetic constitution in female is ZW and male ZZ.

6.1.1 Karyotype:

The particular array of chromosomes that an individual possesses is called its **karyotype** (fig 6.1) which may differ greatly between different species, or sometimes even between particular individuals. Karyotype of individuals are often examined to detect genetic abnormalities, such as those arising from extra or lost chromosomes.

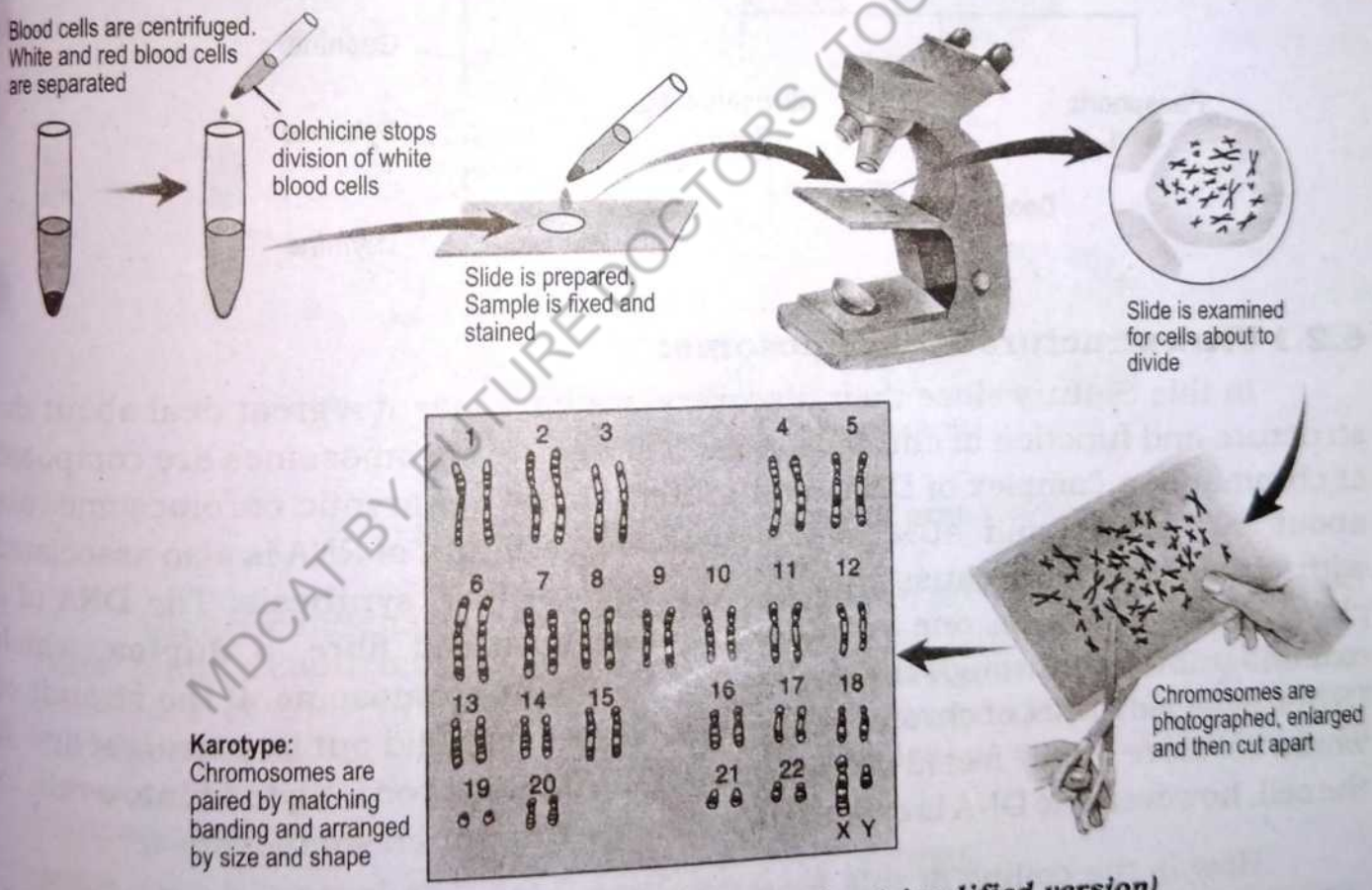
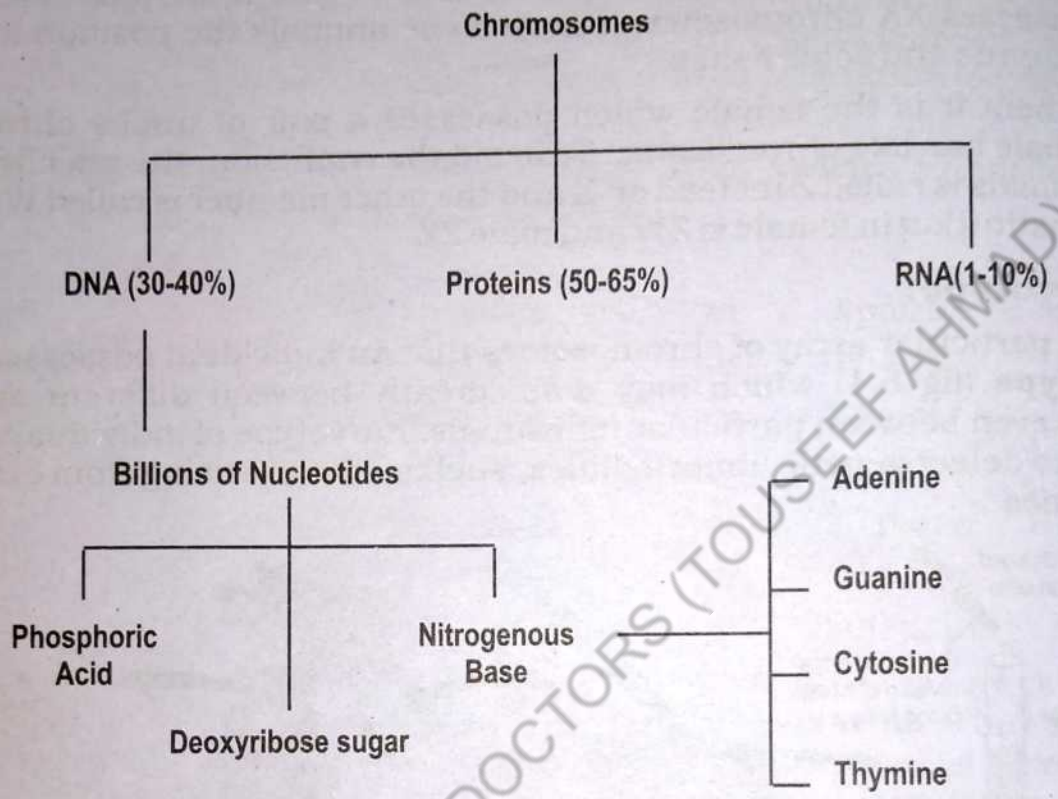


Fig: 6.1 Human karyotype preparation (simplified version)

6.2 CHEMICAL COMPOSITION OF CHROMOSOMES

The chemical composition of chromosomes show that they are made up of Deoxyribo-nucleo protein. Deoxyribo-nucleo protein is composed of DNA and

proteins. The most abundant chromosomal proteins are called **histones**. DNA is made up of billions of units called nucleotides. Whereas each nucleotide is made up of three molecules called phosphoric-acid, deoxy-ribose-sugar and nitrogenous -base, as illustrated below.



6.2.1 Ultra structure of chromosome:

In this century since their discovery, we have learnt a great deal about the structure and function of chromosomes. Eukaryotic chromosomes are composed of chromatin, a complex of DNA, and protein. Most eukaryotic chromosomes are about 60% protein and 40% DNA. A significant amount of RNA is also associated with chromosomes, because they are the sites of RNA synthesis. The DNA of a chromosome exists as one very long double stranded fibre, a **duplex**, which extends unbroken through the entire length of the chromosome. If the strands of DNA from a single set of chromosome in nucleus were laid out in a straight line, it would be more than 7 feet (2 metres) long. This is much too long to fit into a cell. In the cell, however, the DNA is coiled, thus fitting into a much smaller space.

How is the coiling of this long DNA fiber achieved? If we gently disrupt a eukaryotic nucleus and examine the DNA with an electron microscope, we find that it resembles a string of beads. Every 200 nucleotides, the DNA duplex is coiled about a complex of histones, which are small, very basic polypeptides, rich in the amino acids arginine and lysine. Eight of these histones form the core of an assembly called a nucleosome. Because so many of their amino acids are basic,

histones are very positively charged. The DNA duplex, which is negatively charged, is strongly attracted to the histones and wraps tightly around the histone core of each nucleosome. The core thus acts as a "form" that promotes and guides the coiling of the DNA. Further coiling of the DNA occurs when the string of nucleosomes wraps up into higher-order coils called **super coils** (Fig: 6.2).

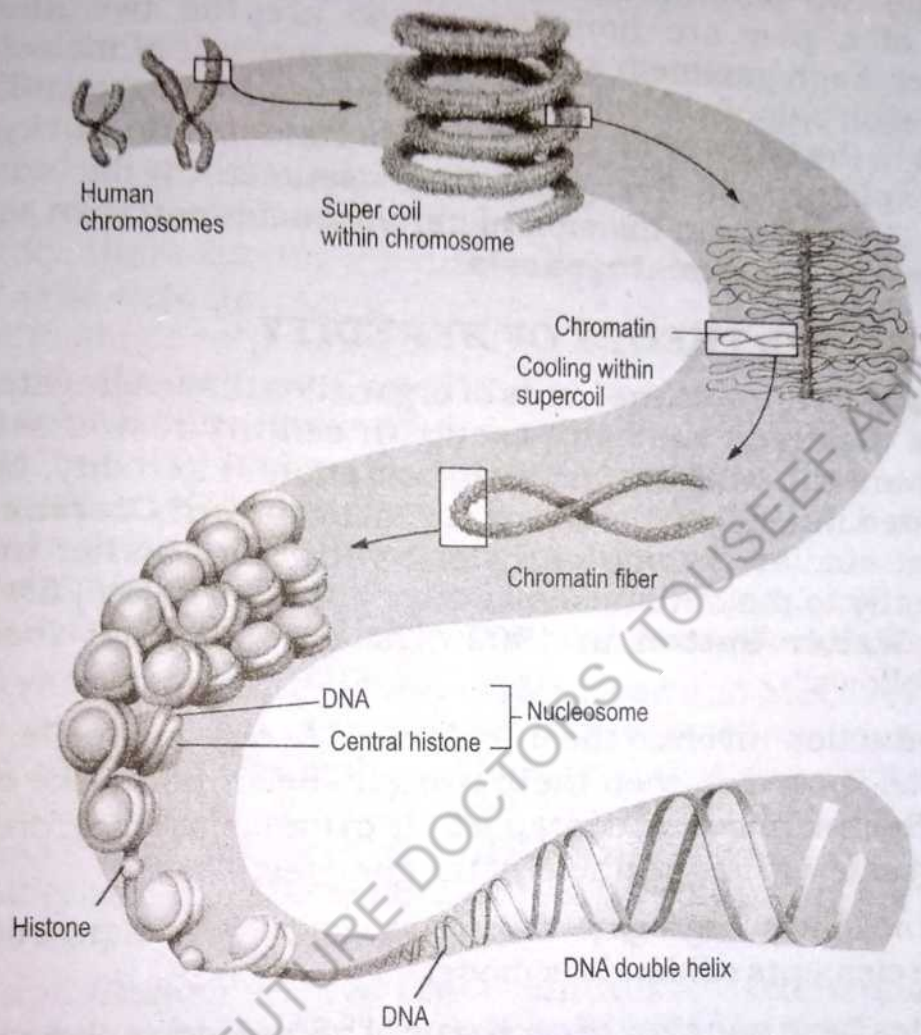


Fig: 6.2 Levels of chromosomal organization

Highly condensed portions of the chromatin are called **hetero chromatin**. Some remain condensed permanently, so that their DNA is never expressed. The remainder of the chromosome, called **euchromatin**, is not condensed except during cell division, when the movement of the chromosomes is facilitated by the compact packaging that occurs at that stage. At all other times, the euchromatin is an open configuration and its genes can be activated.

6.3 CHROMOSOMES AS CARRIERS OF GENES

It has been suggested since the beginning of 20th century that genes are carried in the chromosomes. The chromosomes can be separately identified visually, but the genes are very small units and so far have not been seen even with the best microscope. But we know that genes are molecules borne in the chromosomes of the cell nuclei. First, it is observed that the chromosomes and genes behave so in inheritance, that the genes cannot be considered outside the

chromosomes. At the time of meiosis, the separation of homologous pairs of chromosomes can be seen and it takes place as also required for the segregation of gene pairs. Secondly, we know that in the genotype of every individual, one member of each pair of genes is contributed by one parent and the other by the other parent. This exactly happens in chromosomes, which are in pairs in zygote and each of the two parents contribute one member of the pair. As the two chromosomes of a pair are homologous, so are the two alleles located on homologous loci. Each gamete (egg or sperm) as a result of meiosis contains only one member of each pair of allelic genes. Each egg and sperm contains only one of a pair of genes. It is the basis of all breeding experiments and purity of gametes. All this can be explained, if the genes are assumed to be contained in the chromosomes. The reduction division of chromosomes can then segregate them at the time of **oogenesis** or **spermatogenesis**.

6.4 CHROMOSOMAL THEORY OF HEREDITY

Chromosomes are also the kinds of organelles that segregate regularly when eukaryotic cells divide. In the early twentieth century it was assumed that the chromosomes were the vehicles for the information of heredity, their central role was first suggested in 1900 by the German geneticist **Karl Correns**. Soon after, the observation that similar chromosomes pair with one another in the process of meiosis led directly to the chromosomal theory of inheritance, first formulated by the American, **Walter Sutton** in 1902. The chromosomal theory of heredity postulated as follows:

1. Reproduction involves the initial union of only two cells, egg and sperm. If Mendel's model is correct, then these two gametes must make equal hereditary contributions. Sperm, however, contains little cytoplasm, therefore, the hereditary material must reside within the nuclei of the gametes.

2. Chromosomes segregate during meiosis in a manner similar to that exhibited by the elements of Mendel's model.

3. Gametes have one copy of each pair of homologous chromosomes; diploid individuals have two copies. In Mendel's model gametes have one copy of each element; diploid individuals have two copies.

4. During meiosis, each pair of homologous chromosomes orients on the metaphase plate independent of any other pair. Thus independent assortment of chromosomes is a process suggestive of the independent assortment of factors postulated by **Mendel**.

There was one problem with this theory, as many investigators soon pointed out. If Mendelian traits are determined by factors located on the chromosomes, and if the independent assortment of Mendalian traits reflects the independent assortment of these chromosomes in meiosis, why is it that the number of factors that assort independently of one another in a given kind of organism is often much greater than the number of chromosome pairs that the organism possesses? This seemed a fatal objection, and it led many early researchers to have serious reservations about **Sutton's theory**.

6.4.1 DNA: Evidence of DNA as hereditary material:

Streptococcus pneumoniae, a bacterium associated with certain types of pneumonia occurs in two major forms i.e. the smooth surface cells possessing a capsule are virulent, responsible for pneumonia and the rough surface cells, lacking a capsule are non virulent. When cultured separately the two types give rise to bacteria of their own types, showing that their strains are genetically determined.

During the course of his experiments, **F.Griffith** injected rough surface bacteria called **R-type** into laboratory mice and observed no ill effect on them, whereas the injection of smooth surface bacteria called **S-type** proved fatal for mice. It was also observed that if both the strains of bacteria were heated under high temperature, they are killed and if then injected in separate mice, no ill effects appeared. In some other experiments unexpected results appeared. If live **R-type** i.e. non-virulent type were injected into mice and then additional injections in the same mice were made of heat-killed i.e. dead **S-type** bacteria, high mortality of mice was observed. **Griffith** conducted these experiments in 1928 and at that time, he had no satisfactory explanation for this development. It appeared as if the dead **S-type** bacteria had some how became alive in the mice, but it was obviously unacceptable. However, it was clear that the influence of the heat-killed **S-type** bacteria had transformed the living cells of the non-virulent **R-type** bacteria. The phenomenon in which heat-killed bacteria of one type could have hereditary effect on bacteria of another type is called **transformation**.

Nearly 16 years later, in 1944 **Avery, Macleod** and **McCarty** discovered the true identity of the transforming substance. They tested reactions of heat-killed bacteria for their transforming ability and found out that it was not RNA or various proteins, but only DNA that possessed the transforming ability. If the enzyme, Deoxyribo-nuclease that destroys the DNA was added to the bacteria, the transforming ability was lost. Therefore, it has become clear, beyond any doubt that DNA must be the genetic material.

Hershey and **Chase** observed that if cultures of bacteriophage are labelled with radio active phosphorus (P^{32} for labelling DNA) or with sulphur (S^{35} for labelling protein coat) and the bacteriophage ruptured, the DNA is released and treated with deoxyribonuclease, the DNA breaks up into fragments in a solution. The empty protein coat of the ruptured membrane appear as **coats**. All the P^{32} or S^{35} were made to infect bacteria and multiply and by the help of special technique, all the S^{35} labelled proteins were removed. The new phages formed, contained only P^{32} indicating the presence of DNA molecules. The conclusion appears similar to the transforming principle in bacteria, showing that DNA is the genetic material in phage, transmitted from one generation to the next.

6.4.2 Brief reference to DNA structure:

DNA is a very complex molecule. The units of this molecule are called nucleotide. Each nucleotide itself is made up of three components. They are:

1. Deoxyribose sugar ($C_5H_{10}O_4$)
2. Phosphoric acid (H_3PO_4)
3. Organic bases (Nitrogenous bases)

There are four different types of organic bases found in DNA molecule. Hence there are four different types of nucleotides. They are Adenine, Thymine, Cytosine and Guanine.

Millions of these nucleotides combine to form a single molecule of DNA. The close study of nucleotide reveals that adenine and guanine bases have double ring structure and on the other hand, cytosine and thymine have single ring structure. The two, **adenine** and **guanine** are called **purine-bases** and **cytosine** and **thymine** are called **pyrimidine-bases**.

These nucleotides are joined with one another through Phosphoric-acid in such a way that the C_3 position of one deoxyribose is linked to the C_5 position of the next.

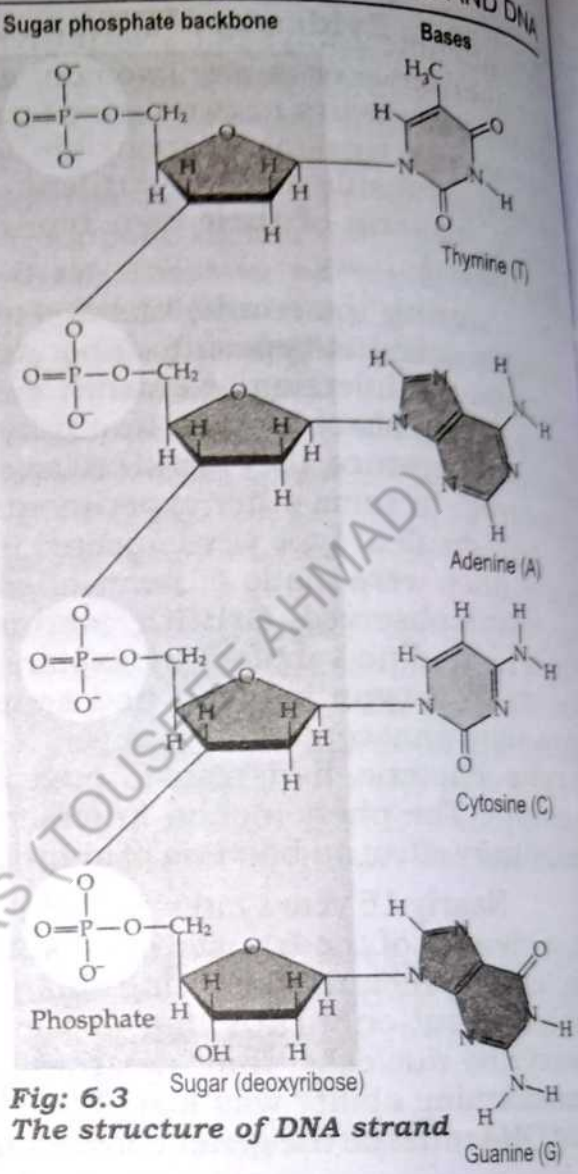


Fig: 6.3
The structure of DNA strand

James D. Watson and **Francis H. Crick in** 1953 suggested a model of DNA, which was based on X-ray diffraction data provided by **Maurice H. F. Willikins**. For their pioneer work all the three scientists received Noble prize in 1962. Rosalind Franklin an expert x-ray crystallographer showed that PO_4 lie on the outer side of molecule, a pivot role enabling Watson and Crick to propose their DNA molecule, but she died of cancer in 1958 at the age of 38.

6.4.3 Watson and Crick model of DNA:

In 1953, **Watson** and **Crick** surprised the scientific world with a concise, one-page paper in the British Journal Nature. The paper reported their molecular model for DNA: the double helix, which has since become the symbol of molecular biology. The beauty of the model was that its structure suggested the basic mechanism of DNA replication.

Watson and Crick suggested ladder type organization of DNA.Each molecule of DNA is made up of two polynucleotide chains, which are twisted around each other and form a double helix. The uprights of the ladder are made up of sugar and phosphate part of nucleotide and the rungs are made up of paired nitrogenous bases. The pairs are always as follows:

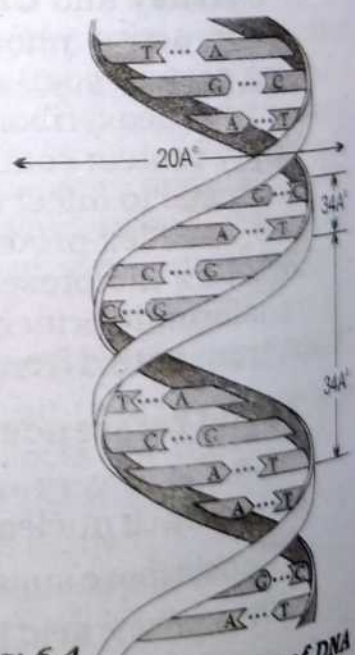


Fig: 6.4
Double Helix structure of DNA

Adenine always pairs with thymine and cytosine with guanine. There is no other alternative possible. Two polynucleotides chains, which are complimentary to each other, are held together by hydrogen bonds. There are two hydrogen bonds between A=T, and three between C≡G. Both polynucleotide strands remain separated by 20A° distance. The coiling of double helix is right handed and complete turn occurs after 3.4A°. Since each nucleotide occupies 3.4A° distance along the length of a polynucleotide strand, 10 mononucleotide occur per complete turn.

The **Watson-Crick** model explained **Chargaff 's** rules. Wherever one strand of a DNA molecule has an A, the partner strand has a T and G in one strand is always paired with a C in the complimentary strand. Therefore, in the DNA of any organism, the amount of adenine equals the amount of thymine, and the amount of guanine equals the amount of cytosine. Although the base-pairing rules dictate the combinations of nitrogenous bases that form the rungs of the double helix, they do not restrict the sequence of nucleotide along each DNA strand. Thus, the linear sequence of the four bases can vary in countless ways, and each gene has a unique order, or base sequence.

6.4.4 Replication of DNA

The **Watson-Crick** model immediately suggested that the basis for copying the genetic information is complimentary. One chain of the DNA molecule may have any conceivable base sequence, but this sequence completely determines that of its partner in the duplex. If the sequence of one chain is ATTGCAT, the sequence of its partner in the duplex must be TAACGTA. Each chain in the duplex is a complementary mirror image of the other. To copy the DNA molecule, one need only **unzip** it and construct a new complimentary chain along each naked strand.

Replication is semi conservative:

The form of DNA replication suggested by the Watson-Crick model is called semi conservative because, after one round of replication, the original duplex is not conserved; instead, each strand of the duplex becomes part of another duplex.

The complimentary nature of the DNA duplex provides a ready means of duplicating the molecule. If one were to unzip the molecule, one would need only to assemble the appropriate complimentary nucleotide on the exposed single strands to form two daughter duplexes of the same sequence. This prediction of the Watson Crick model was tested in 1958 by **Mathew Meselson** and **Frank Stahl** of the California Institute of Technology (Figure 6.5). These two scientists grew bacteria for several generations in a medium containing the heavy isotope of nitrogen N^{15}, so the DNA of the bacteria was eventually denser than normal. They then transferred the growing cells to a new medium containing the lighter isotope N^{14} and harvested the DNA at various intervals.

At first the DNA that the bacteria manufactured was all heavy. But as the new DNA that was being formed incorporated the lighter nitrogen isotope, DNA density fell. After one round of DNA replication was complete, the density of the bacterial DNA had decreased to value intermediate between all-light isotope and all-heavy isotope DNA. After another round of replication, two density classes were

observed, one intermediate and the other light, corresponding to DNA that included none of the heavy isotope. These results indicated that after one round of replication, each daughter DNA duplex possessed one of the labelled heavy strands of the parent molecule. When this hybrid duplex replicated, it contributed one heavy strand to form another hybrid duplex and one light strand to form a light duplex. **Meselson** and **Stahl's** experiment thus clearly confirmed the prediction of the Watson-Crick model that DNA replicates in a semi conservative manner.

A DNA molecule copies (replicates) itself by separating its two strands and using each as a template to assemble a new complementary strand, thus forming two daughter duplexes. The two strands are assembled in different directions.

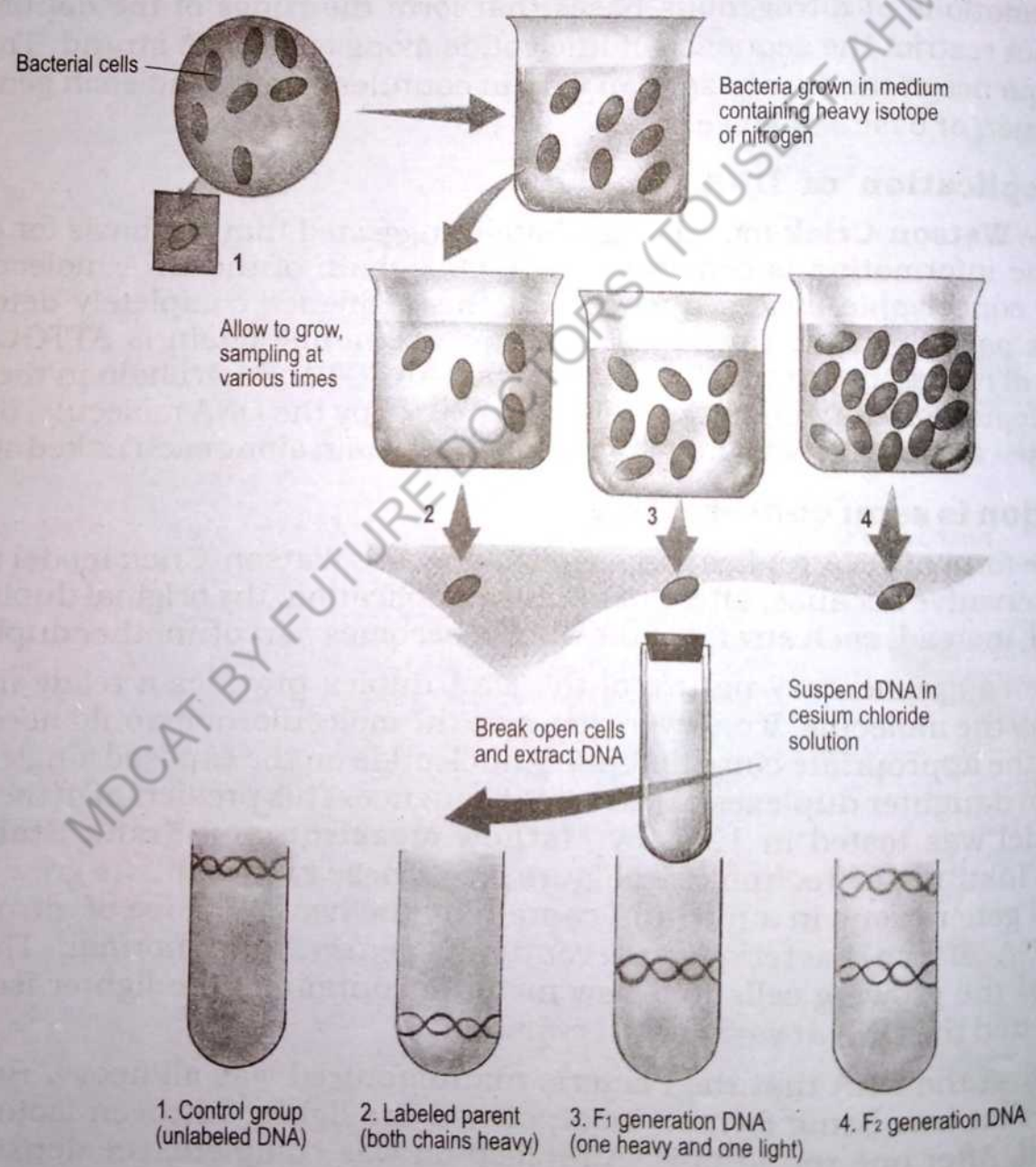


Fig: 6.5 Meselson and Stahl experiment

6.5 GENES ---- The Units of Hereditary Information

In 1902 a British physician, Archibald Garrod, who was working with one of the early Mendelian geneticists, his countryman William Bateson, noted that certain diseases among his patients were more prevalent in their families. Indeed, if one examined several generations within such families, some of these disorders seemed to behave as if they were controlled by simple recessive alleles.

Garrod concluded that these disorders were Mendelian traits and that they had resulted from changes in the hereditary information that had occurred in the past to an ancestor of the affected families. **Garrod** examined several of these disorders in detail. In one, **alkaptonuria**, the patients passed urine that rapidly turned black on exposure to air. Such urine contained homogentisic acid (alkapton), which is oxidized when exposed to air. In normal individuals homogentisic acid is broken down into simpler substances, but the affected patients were unable to carry out that breakdown. With considerable insight, Garrod concluded that the patients suffering from alkaptonuria lacked the enzyme necessary to catalyze this breakdown and, more generally, that inherited disorders might reflect enzyme deficiencies.

Genome:

The total genomic constitution of an individual is known as **genome**. In a bacterial cell, a single circular chromosome alongwith plasmid is genome of bacteria, while in a human being all twenty two pairs of autosome alongwith a pair of sex chromosomes constitute genome.

6.5.1 The one gene-one enzyme hypothesis:

From **Garrod's** finding it is but a short leap of intuition to guess that information encoded within the DNA of chromosomes is used to specify particular enzymes. This point was not actually established, however, until 1941, when a series of experiments by the Stanford University geneticists **George Beadle** and **Edward Tatum** finally provided definitive evidence on this point. **Beadle** and **Tatum** deliberately set out to create Mendelian mutations in the chromosomes; they then studied the effects of these mutations on the organism.

Creating genetic differences: One of the **Beadle** and **Tatum's** experiments produced clear-cut results. The researchers made an excellent choice of experimental organism. They chose the bread mold *Neurospora*, a fungus that can readily be grown in the laboratory on a defined medium (a medium that contains only known substances such as glucose, sodium chloride, rather than some uncharacterized cell extract such as ground-up yeasts). **Beadle** and **Tatum** induced mutations by exposing Neurospora spores to X-rays. They then allowed the progeny to grow on complete medium (a medium that contained all necessary metabolites). In this way the investigators were able to keep alive strains that, as a result of the earlier irradiation, had experienced damage to their DNA in a region encoding the ability to make one or more of the compounds that the fungus needed for normal growth. Change of this kind in the DNA is called **mutation**, and strains or organisms that have under gone such change (in this case losing the ability to use one or more compounds) are called **mutants**.

Beadle and Tatum developed three different Mutant strains of neurospora by irradiating the spores by X-rays and ultra violet rays (Fig: 6.6).

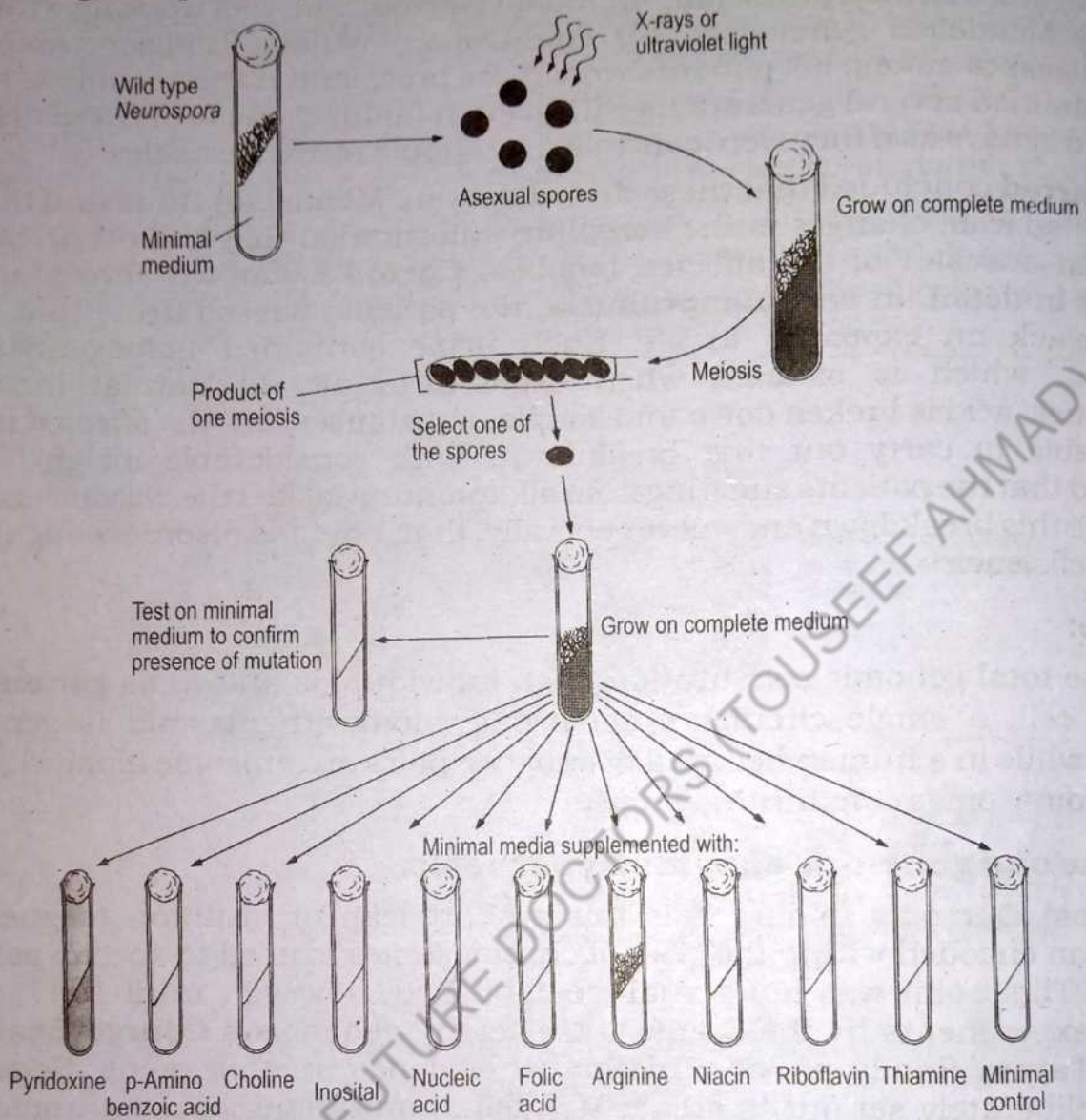


Fig: 6.6
Beadle and Tatum's procedure for isolating nutritional mutations in Neurospora

The three mutant strains had following characteristics:

MUTANT 1- would grow if O, C or A were added to the minimal medium of salts, sugar and biotin.

MUTANT 2- would grow if either C or A was added to the minimal medium

MUTANT 3- would grow only if A was added to the minimal medium.

O= Orinithine, C=Citruline and A =Arginine.

Beadle and Tatum suggested a hypothesis for these observations. According to them each mutation alter a single gene that controls one step in the synthesis of a particular kind of molecule. Such a chain of reaction may be shown as under:

Some Prior	Gene 1	Gene 2	Gene 3
Substance	O	C	A

This shows that gene I functions by converting some prior substance into O. The gene 2 by converting O into C, and gene 3 by converting C into A. If X-rays damaged gene 1, then the mold could no longer grow, unless its normal function of making O was compensated for. Adding product O to the minimal medium would do this. But it is to be noted that adding C or A can overcome this deficiency. It means that the compound is being supplied in a somewhat more advanced stage of synthesis, thus bypassing the normal functions of gene 2 and 3.

If gene 3 mutates, then this deficiency cannot be overcome by adding substances O or C. Gene 3 is responsible for converting C to A. In this case, there is no alternative except to add A to the medium..

The geneticists concluded that genes produce their effects by specifying the structure of enzymes, and that each gene encodes the structure of a single enzyme. They called this relationship the one gene-one enzyme hypothesis (Fig: 6.7).

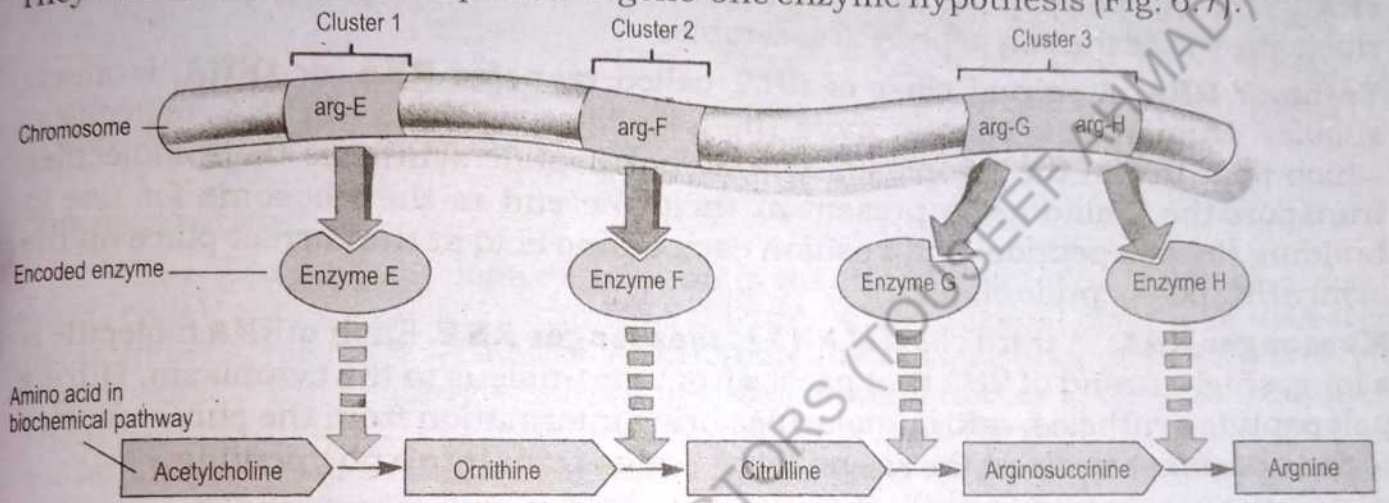


Fig: 6.7 Evidence for the one gene-one enzyme hypothesis

Enzymes are responsible for catalyzing the synthesis of all parts of the cell. They mediate the assembly of nucleic acids, the synthesis of proteins, carbohydrates, fats and lipids. From the hair on your head to the toenails of your feet, all of you represents the products of enzyme-directed chemical reactions. By specifying your enzymes, DNA specifies you.

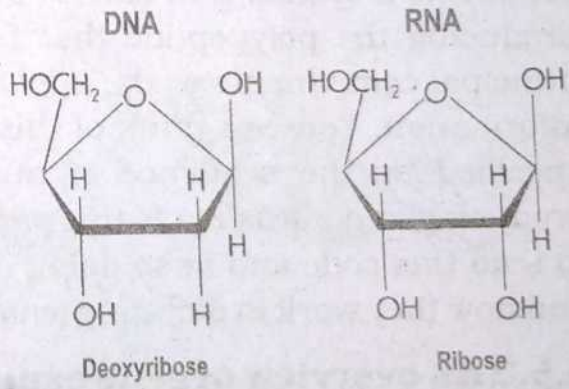


Fig: 6.8 How RNA is different from DNA

6.5.2 Cells use RNA to make Protein:

To find out how a cell uses its DNA to direct the production of particular proteins, perhaps the simplest question you might ask is "Where in the cell are proteins made?" You can answer this question by placing cells for a short time in a medium containing radioactive amino acids; the cells will take up the radioactively labeled amino

acids for the short time that they are exposed to them. This is known as **pulse** labeling as the cells are exposed to a pulse of radioactive label. When investigators looked to see where in the cells radioactive proteins first appeared, they found that proteins were assembled not in the nucleus, where most of the DNA is located but rather in the cytoplasm, on large protein aggregates called ribosomes. These little polypeptide-making factories proved to be very complex, containing over 50 different proteins. They also contain a different sort of molecule, RNA. RNA is similar to DNA (Figure: 6.8) and its presence in ribosomes hints that RNA molecules play an important role in polypeptide synthesis.

A cell contains many kinds of RNA. There are three major classes;

Ribosomal RNA: The class of RNA found in ribosomes is called **ribosomal RNA**, or **rRNA**. During polypeptide synthesis, rRNA molecules provide the site on the ribosome where the polypeptide is assembled.

Transfer RNA: A second class of RNA, called **transfer RNA**, or **tRNA**, is much smaller. Human cells contain more than 40 different kinds of tRNA, molecules, which float free in the cytoplasm. During polypeptide synthesis tRNA molecules transport the amino acids present at their one end to the ribosome for use in building the polypeptide, and position each amino acid at the correct place on the elongating polypeptide chain.

Messenger RNA: A third class of RNA is **messenger RNA**. Each mRNA molecule is a long, single strand of RNA that passes from the nucleus to the cytoplasm. During polypeptide synthesis, mRNA molecules bring information from the chromosomes to the ribosomes to direct the assembly of amino acids into a polypeptide.

These molecules, together with ribosomal proteins and certain enzymes, constitute a system that carries out the task of reading the genetic message and producing the polypeptide that the particular message specifies. They are the principal components or the apparatus that a cell uses to translate its hereditary information. You can think of this information as a message written in the code specified by the sequence of nucleotides in the DNA. The cell's polypeptide producing apparatus reads this particular polypeptide. Biologists have also learned to read this code and in so doing have learned a great deal about what genes are and how they work in dictating what a protein will be like and when it will be made.

6.5.3 An overview of gene expression:

The hereditary apparatus of your body works in much the same way as that of the most primitive bacteria -all organisms use the same basic mechanism. An RNA copy of each active gene is made and at a ribosome the RNA copy directs the sequential assembly of a chain of amino acids. There are many minor differences in the details of gene expression between bacteria and eukaryote, and a single major difference. The basic apparatus used in gene expressions, however, appears to be the same in all organisms (Fig:6.9); it apparently has persisted virtually unchanged since early in the history of life. The process of gene expression occurs in two phases, which are called **transcription** and **translation**.

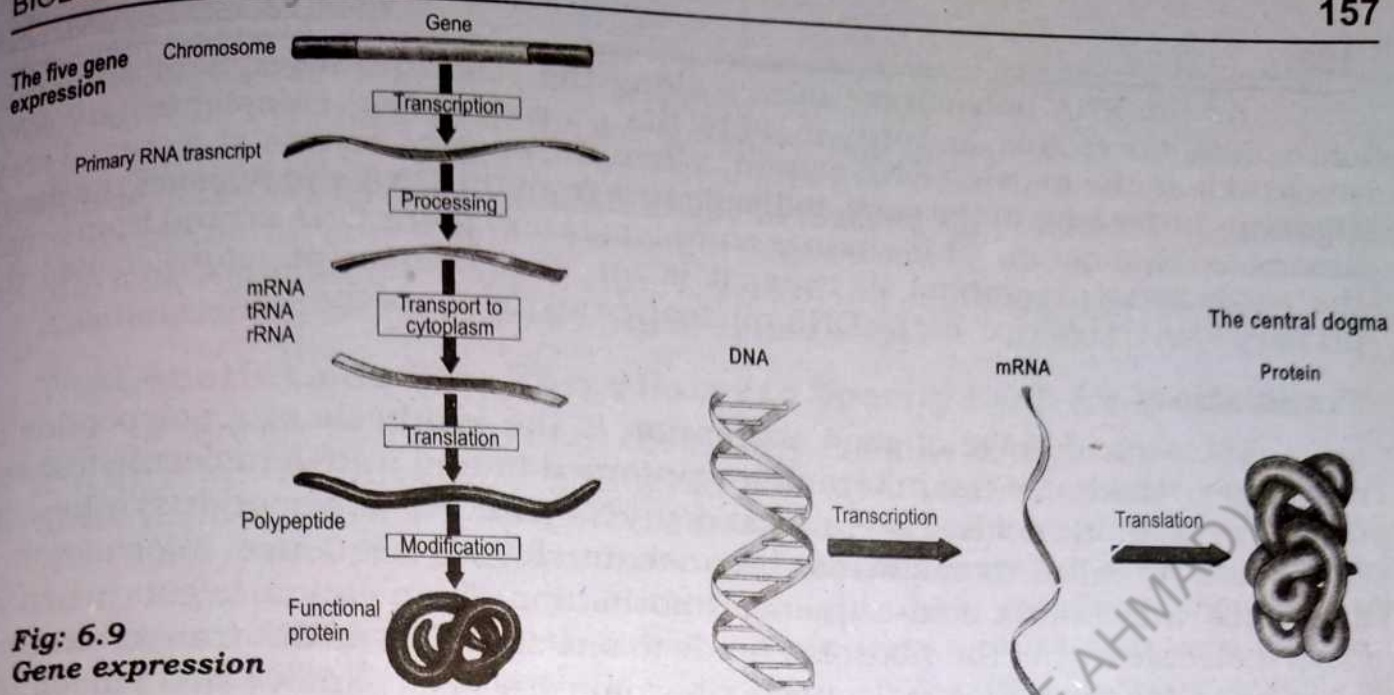


Fig: 6.9
Gene expression

Transcription:

The first stage of gene expression is the production of an RNA copy of the gene, called messenger RNA or mRNA (Figure : 6.10). Like all classes of RNA that occur in cells, mRNA is formed on a DNA template. The production of RNA is called transcription; the messenger RNA molecule (as well another RNA classes such as rRNA and tRNA) is said to have been transcribed from the DNA. Transcription is initiated when a special enzyme, called an **RNA polymerase**, binds to a particular sequence of nucleotides on one of the DNA strands. This sequence is located at the edge of a gene

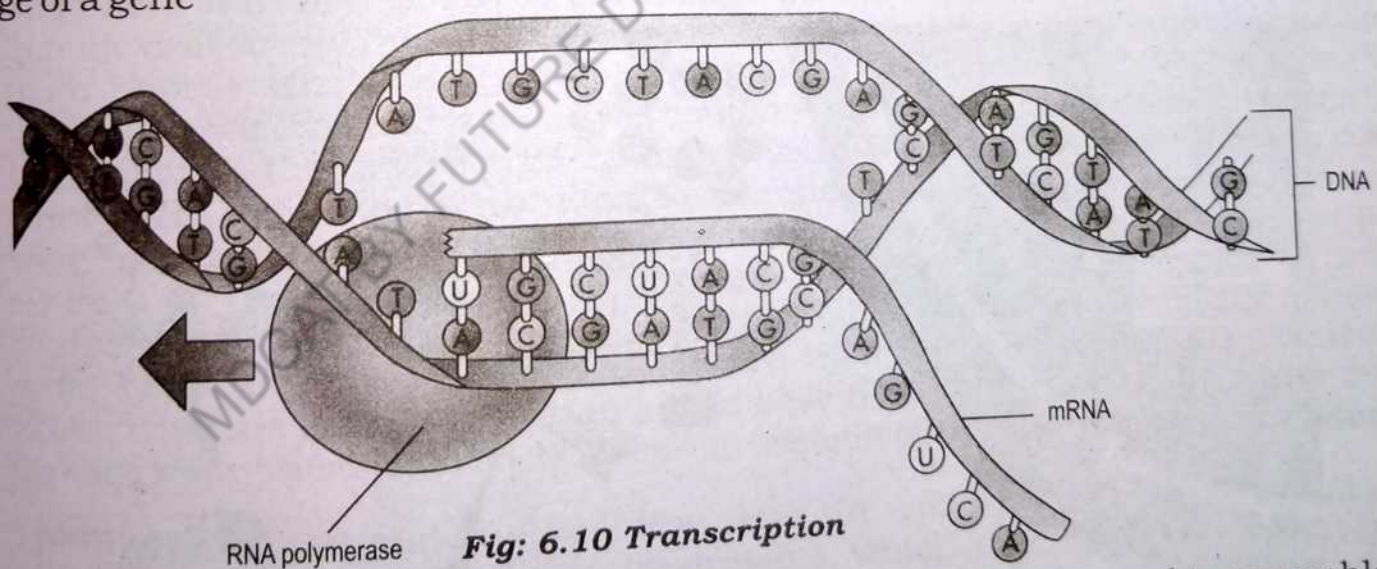


Fig: 6.10 Transcription

Starting at that end of the gene, the RNA polymerase proceed to assemble a single strand of RNA with a nucleotide sequence complementary to that of the DNA strand it has bound. Complementarity refers to the way in which the two single strands of DNA that form a double helix relate to one another, with A (adenine) pairing with T (thymine) and G (guanine) pairing with C (cytosine). An RNA strand complementary of thymine is uracils.

As the RNA polymerase moves along the strand into gene, encountering each DNA nucleotide in turn, it adds the corresponding complementary RNA nucleotide to the growing RNA strand. When the enzyme arrives at a special **stop** signal at the far edge of the gene, it disengages from the DNA and releases the newly assembled RNA chain. This chain is complementary to the DNA strand from which the polymerase assembled it; thus, it is an RNA **transcript** (copy), called the primary RNA transcript, of the DNA nucleotide sequence of the gene.

Translation:

The second stage of gene expression is the synthesis of a polypeptide by ribosomes, which use the information contained in and mRNA molecule to direct the choice of amino acids. This process of mRNA-directed polypeptide synthesis by ribosomes is called **translation** because nucleotide-sequence information is translated into amino acid-sequence information. Translation begins when an rRNA molecule within the ribosome binds to one end of an mRNA transcript. Once it has bound to the mRNA molecule, a ribosome proceeds to move along the mRNA molecules in increments of three nucleotides. At each step, it adds an amino acid to a growing polypeptide chain. It continues to do this until it encounters a "stop" signal that indicates the end of the polypeptide. It then disengages from the mRNA and releases the newly assembled polypeptide. An overview of protein synthesis is presented in figure 6.11.

During translation, the codones of mRNA base pair with the anticodones of tRNA molecules carrying specific amino acids.

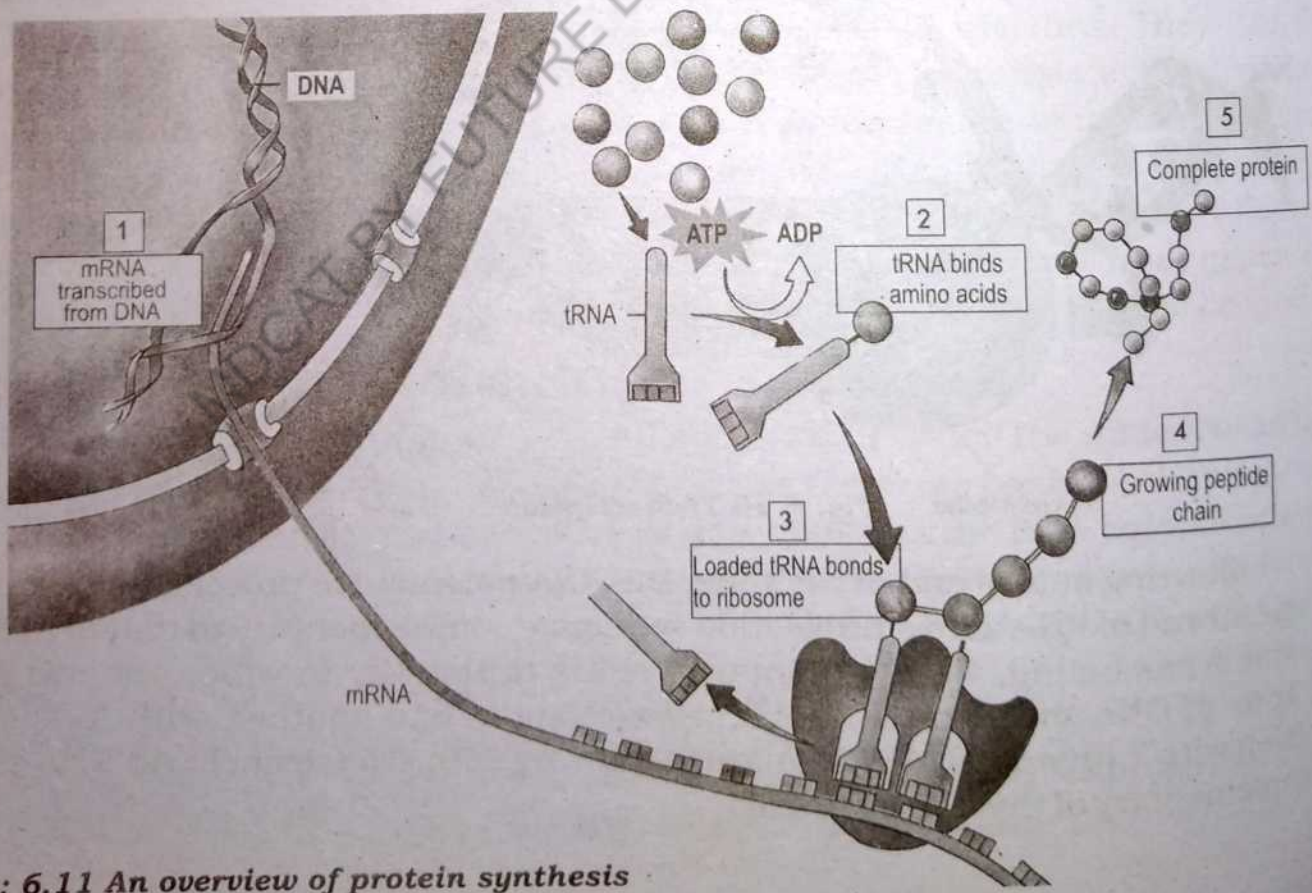


Fig: 6.11 An overview of protein synthesis

6.5.4 The genetic code:

We have used the word code several times to refer to the information stored in DNA and ultimately translated into the amino acid sequence of proteins. This genetic code is conceptually similar to Morse code: One set of symbols (bases in nucleic acids, dots and dashes in Morse code) can be translated into another set of symbols (amino acids in proteins, letters of the alphabet). The question is, What combinations of bases stand for which amino acids?

The Genetic Code Uses Three Bases to Specify Each Amino Acid:

There are four different bases in DNA: adenine (A), cytosine (C), guanine (G), and thymine (T). There are also four bases in RNA: adenine, cytosine, guanine and uracil (U).But there are 20 different basic amino acids in proteins, so the bases cannot serve as a one-to-one code for amino acids. There are simply not enough of them. Perhaps though, the genetic code might use a short sequence of bases to encode each amino acid, just as Morse code uses a short sequence of dots and dashes to encode the letters of the alphabet. If a sequence of two bases codes for an amino acid, then there will be 16 (4x4) possible combinaions of bases. This isn't enough either. Three bases per amino acid, however, gives 64 (4x4x4) possible combinations, which is more than enough. Under the assumption that nature operates as economically as possible, biologists hypothesized that the genetic code must be the triplet of nitrogenous bases. Three bases specify one amino acid. In 1961, Francis Crick and three co-workers demonstrated that this hypothesis is correct.

A few requirements must be met for any language to be understood. The users must know what the words mean, where words start and stop, and where sentences start and stop. The **Crick** experiments demonstrated that words of the genetic code are all three bases long and that a set of three bases means one amino acid. Shortly after this discovery, researhers began to decipher the code. They ground up bacteria and isolated the components needed to synthesize proteins. To this mixture , they added artificial messenger RNA, which allowed them to control what words were to be transcribed. Researchers could then see which amino acids were incorporated into the resulting proteins. For example, an RNA composed entirely of uracil (UUUUUU...) directed the mixture to synthesize a protein composed solely of phenylalanine. Therefore, the triplet specifying phenylalanine must be UUU. Because the genetic code was deciphered using these artificial RNAs, the code is usually written as the base triplets in messenger RNA that code for each amino acid (Table 6.1). These messenger RNA triplets are called **codons**.

What about punctuation? How does the cell recognize where codons start and stop and where codes for entire proteins, which are composed of many amino acids, start and stop? Research showed that the codon AUG signals **start**--that is, the beginning of a protein(start codon). Three codons, UAG, UAA and UGA, signal **stop**--the end of a protein (stop codon). Now, if all the codons have three bases, and the beginning and end of a proetin are specified, then punctuation between codons is unnecessary. To see why this is so, consider what would happen if English used only three letter words: A sentence such as **Themansawthecat** would be perfectly understandable, even without spaces between the words, as

long as the reader knew where the sentence started and stopped. The genetic code does'nt need, and doesn't have, punctuation between codons.

Table 6.1 The genetic code (Codons of mRNA)

First base	Second base U		Second base C		Second base A		Second base G		Third base
U	UUU	Phenylalanine	UCU	Serine	UAU	Tyrosine	UGU	Cysteine	U
	UUC	Phenylalanine	UCC	Serine	UAC	Tyrosine	UGC	Cysteine	C
	UUA	Leucine	UCA	Serine	UAA	**Stop**	UGA	**Stop**	A
	UUG	Leucine	UCG	Serine	UAG	**Stop**	UGG	Tryptophan	G
C	CUU	Leucine	CCU	Proline	CAU	Histidine	CGU	Arginine	U
	CUC	Leucine	CCC	Proline	CAC	Histidine	CGC	Arginine	C
	CUA	Leucine	CCA	Proline	CAA	Glutamine	CGA	Arginine	A
	CUG	Leucine	CCG	Proline	CAG	Glutamine	CGG	Arginine	G
A	AUU	Isoleucine	ACU	Threonine	AAU	Asparagine	AGU	Serine	U
	AUC	Isoleucine	ACC	Threonine	AAC	Asparagine	AGC	Serine	C
	AUA	Isoleucine	ACA	Threonine	AAA	Lysine	AGA	Arginine	A
	AUG	Start (Methionine)	ACG	Threonine	AAG	Lysine	AGG	Arginine	G
G	GUU	Valine	GCU	Alanine	GAU	Aspartic acid	GGU	Glycine	U
	GUC	Valine	GCC	Alanine	GAC	Aspartic acid	GGC	Glycine	C
	GUA	Valine	GCA	Alanine	GAA	Glutamic acid	GGA	Glycine	A
	GUG	Valine	GCG	Alanine	GAG	Glutamic acid	GGG	Glycine	G

Though there are only 20 amino acids for which to code, there are 60 codons, in addition to the start and stop codons. All 60 codons are used in the genetic code. The genetic code is thus highly redundant, or degenerate. In other words, a single amino acid may be specified by several codons. For example, six different codons all code for arginine(Table 6.1).Even though the code is redundant, however, it is not ambiguous: Each codon specifies one, and only one, amino acid.

Decoding:

The mRNA ribosome exposes only a three nucleotide sequence which is said to the genetic code. The tRNA carrying a particular amino acid recognize this code, it possess anticodon series for this site and thus binds to mRNA. The phenomenon is known as decoding. The decoding is an essential process of translation.

6.6 MUTATION

The gene function to determine the ultimate characteristics of phenotype. They achieve this goal by controlling biochemical processes in organisms during growth and adult life. Each biochemical process is divisible into a number of successive steps, which are all under genic control through specific enzymes. **Beadle** and **Tatum** suggested one-gene-one-enzyme hypothesis, which meant that each single reaction is controlled by a single gene i.e. the gene functions to control the production; function and specificity of an enzyme. As genes are the hereditary

material, carrying hereditary instructions, any alteration in the genes would also change the ability of cells to carry out biochemical reactions, and therefore affect the phenotype.

> Chromosome mutations can be the result of structural changes. Although most of these lead to abnormal gametes and offsprings, some no doubt have played a role in evolutionary history.

Although the genes along with their chromosomes are fairly stable and transmit heredity more or less unchanged. They sometimes undergo changes called Mutation. Mutation is any change in the amount, organizations or content of genetic material. It does not include the exchange as a result of recombination between homologous chromosomes. Mutation may be obvious and observable by cytological techniques. Some changes in chromosomes are called chromosomal aberrations. They may be however invisible, when they are in genes. Both types of mutations when passed from adult to the offspring alter the hereditary instructions.

The chromosomal aberrations are concerned with the visible changes in the structure of the chromosome. A small segment of a chromosome may be missing a situation called **deletion** (Fig: 6.12) or a part of chromosome be present in excess to the normal chromosome and called **duplication**. The transfer of segment of chromosome to a non-homologus chromosome is called **translocation**. The reversal in the sequence of genes within the chromosomal aberrations is called **inversion** which alter either the amount of genetic material or arrangement of genes in a normal sequence, they have important effects on heredity. The deletion in one chromosome of a pair may be harmful for the individual, but may be lethal if absent in both chromosomes of the pair. Duplication produces abnormalities of form and function. Inversions reduce crossing over and translocations may give rise to varieties within species.

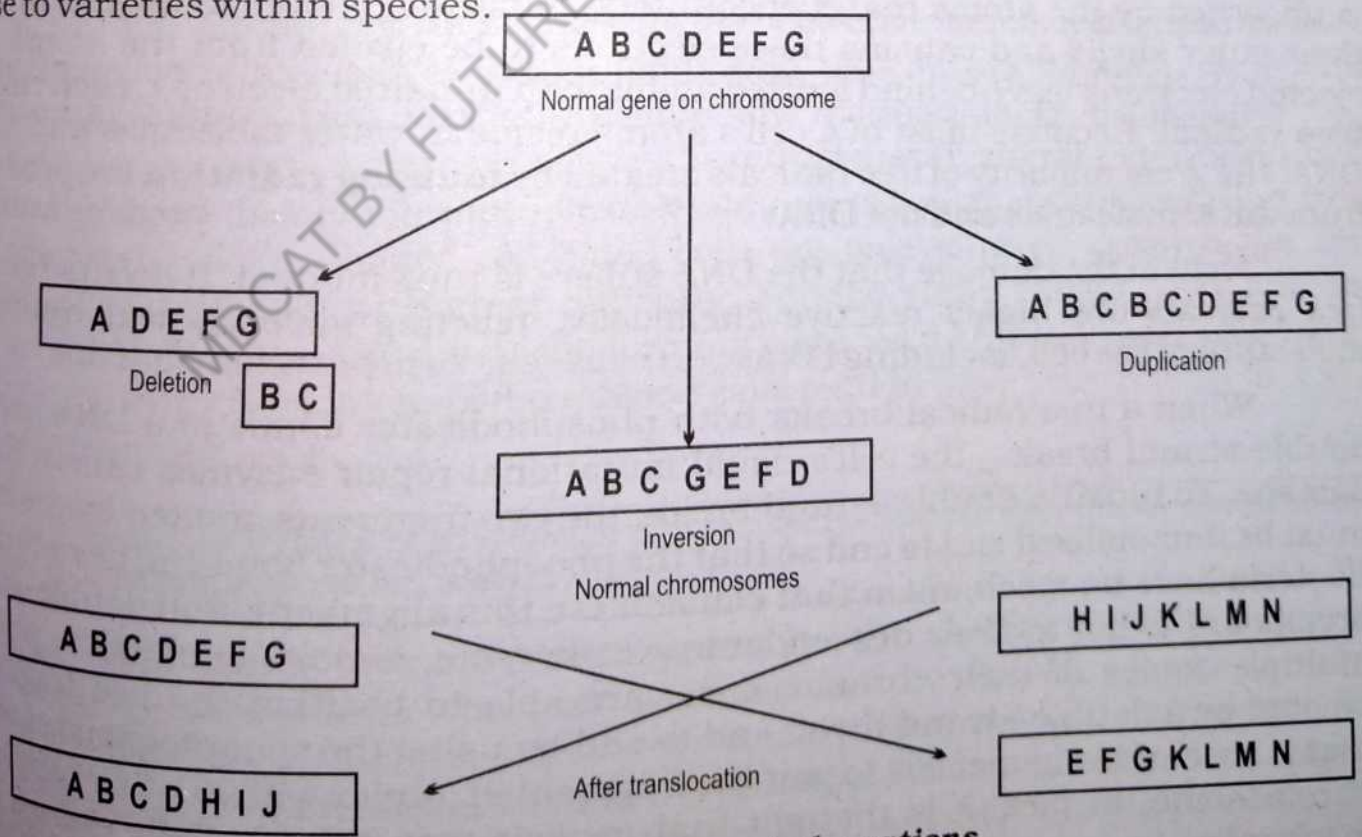


Fig: 6.12 Chromosomal aberrations

Gene mutation:

A change in the genetic message of a cell is also referred to as a mutation. We will discuss mutational changes that affect the message itself, producing alterations in the sequence are called point mutations, since they usually involve only one or a few nucleotide. In both bacteria and eukaryote individual genes may move from one place on the chromosome to another by a process called transposition. When a particular gene moves to different location, there is often an alteration in its expression or in that of the neighboring genes. In eukaryote large segments of chromosomes may change their relative location or undergo duplication. Such **chromosomal rearrangement** often has drastic effects on the expression of the genetic message.

Point mutations, involving only one or a few nucleotide, result either from chemical or physical damage to the DNA or from spontaneous pairing errors that occur during DNA replication. The first class of mutation is of particular practical importance because modern industrial societies produce and release into the environment many chemicals capable of damaging DNA. These chemicals are called **mutagens**.

DNA damage:

Although there are many different ways in which a DNA duplex can be damaged, three are of major importance: (i) ionizing radiation, (ii) ultraviolet radiation, and (iii) chemical mutagens.

(i) Ionizing radiation :

High-energy radiation, such as X-rays and gamma rays, is highly mutagenic. Nuclear radiation is of this sort. When such radiation reaches a cell, it is absorbed by the atoms that it encounters, imparting energy to the electrons of their outer shells and causing these electrons to be ejected from the atoms. The ejected electrons leave behind ionized atoms with unpaired electrons, each called a **free radical**. Because most of a cell's atoms reside in water molecules and not in DNA, the great majority of free radicals created by **ionizing radiation** are produced from water molecules and not DNA.

Most of the damage that the DNA suffers is thus indirect. It occurs because free radicals are highly reactive chemically, reacting violently with the other molecules of the cell, including DNA.

When a free radical breaks both phosphodiester bonds of a DNA helix _a double-strand break _ the cell's usual mutational repair enzymes cannot fix the damage. To repair a double-strand break, the two fragments created by the break must be immobilized end to end so that the phosphodiester bond can be re-formed. Bacteria have no mechanism that can achieve this alignment, and double-strand breaks are lethal to their descendants. Eukaryote, almost all of which possess multiple copies of their chromosomes, are able to position the two fragments created by a double-strand break end to end by using the synaptonemal complex that is assembled in meiosis to pair the fragmented duplex with another copy of the chromosome. In fact, it is thought that meiosis may have initially evolved as a mechanism to repair double strand breaks in DNA.

(ii) Ultraviolet radiation:

Ultraviolet (UV) radiation, the component of sunlight that leads to suntan (sunburn), is much lower in energy than are X-rays. When molecules absorb UV radiation, the radiation does not impart enough energy to cause the molecules to eject electron; consequently, free radicals are not formed. The only molecules that are capable of absorbing UV radiation, in fact, are certain organic ring compounds.

(iii) Chemical mutagens:

Many mutations result from the direct chemical modification of the DNA bases. The chemicals that act on DNA fall into three classes: (i) chemicals that look like DNA nucleotides but pair incorrectly when they are incorporated into DNA, (ii) chemicals that remove the amino group from adenine or cytosine, causing them to mispair; and (iii) chemicals that add hydrocarbon groups to nucleotide bases, also causing them to mispair.

6.6.1 Example of gene mutation:

(a) Sickle cell anaemia:

Sickle cell anaemia is a heritable disorder in which the affected individuals are unable to transport oxygen to their tissues properly because the molecules within red blood cells that carry oxygen, molecules of the protein hemoglobin, are defective. When oxygen is scarce, these effective hemoglobin molecules become insoluble and combine with one another, forming stiff, rod like structures. This results in the formation of sickle shaped red blood cells.

Surprisingly, the haemoglobin that occurs in such defective red blood cells differs from that which occurs in normal red blood cells in only one out of a total of about 300 amino acid molecules. In the defective hemoglobin, one molecule of valine occurs in place of the glutamic acid that occurs in the same position in normal hemoglobin. Red blood cells that contain large proportions of such defective molecules become sickle-shaped and stiff; normal red blood cells are disk-shaped and much more flexible. As a result of their stiffness and irregular shape, the sickle-shaped red blood cells are able to move through the smallest blood vessels only with great difficulty. For the same reason, they also tend to accumulate in the blood vessels, forming clots. As a result, people who have large proportions of sickle-shaped red blood cells tend to have intermittent illness and a shortened life span.

> Sickle-cell disease is an example of a human genetic disorder that is controlled by incompletely dominant alleles.

Individuals who are heterozygous for the sickle cell allele are generally indistinguishable from normal persons. In the blood of people who are heterozygous for this trait, however, some of the red cells show the sickling characteristic when they are exposed to low levels of oxygen. The allele responsible for the sickle cell characteristic is particularly common among people of African descent.

(B) Phenylketonuria:

One of the example of a relatively infrequent genetic disorder is phenylketonuria (PKU), a hereditary condition in which the affected individuals are unable to break down the amino acid phenylalanine. In such individuals, phenylalanine is instead converted to other chemicals that accumulate in the bloodstream. Although not harmful to an adult, these abnormal derivatives of phenylalanine are harmful to infants because they interfere with the development of brain cells. An infant with this disorder suffers severe mental retardation, and affected individuals rarely live more than 30 years. When it is detected early enough, however, PKU can be treated nutritionally and individuals with this genetic constitution can then develop and mature normally.

Phenylketonuria is a recessive disorder caused by a mutant allele of the gene encoding the enzyme that normally breaks down phenylalanine. Only individuals homozygous for the mutant allele develop the disorder.

KEY POINTS

- The geneticists concluded that genes produce their effects by specifying the structure of enzymes, and that each gene encodes the structure of a single enzyme. They called this relationship the one gene-one enzyme hypothesis.
- A cell contains many kinds of RNA.
- Transcription is initiated when a special enzyme, called an RNA polymerase, binds to a particular sequence of nucleotides on one of the DNA strands, a sequence located at the edge of a gene.
- The second stage of gene expression is the synthesis of a polypeptide by ribosomes. The process in which mRNA-directed polypeptide synthesis by ribosomes is called translation.
- Sickle cell anaemia is a heritable disorder, in which the affected individuals are unable to transport oxygen.
- Phenylketonuria is a recessive disorder caused by a mutant allele of the gene encoding the enzyme that normally breaks down phenylalanine.

EXERCISE

1. Encircle the most correct choice:

i) Cells use to make protein
a) DNA b) Nucleus c) RNA d) Chromosomes

ii) Base present in RNA but not in DNA
a) Adenine b) Guanine c) Cytosine d) Uracil

iii) The chromosome number in man is
a) 3 pairs b) 13 pairs c) 23 pairs d) 33 pairs

iv) One complete turn of DNA contains
a) 2 nucleotides b) 5 nucleotides
c) 10nucleotides d) 20 nucleotides

v) To specify an amino acid genetic code uses
a) One base b) Two bases
c) Three bases d) Four bases

vi) Type of chromosome when contromere is located at the centre
a) Metacentric b) Submetacentric
c) Telocentroic d) Acrocentric

vii) Which tripple base sequence do not decode isoleucine amino acid?
a) AUU b) AUC
c) AUA d) AUG

viii) Which one is the true statement for translocation regarding chromosomal aberration
a) A segment of chromosome missing
b) A segment of chromosome present in excess
c) Transfer of segment of chromosome to non-homologous chsomosome
d) A segment of chromosome is inverted

ix) Which statement is not true for sickle cell anaemia
a) Heritable disorder
b) Defective oxygen transfer to tissues
c) Red blood cell becomes sickle shaped
d) Alanine ouccus in place of glutamic acid

x) Which statement is not true for transcription during gene expression
a) Production of an RNA copy of the gene
b) DNA polymerase initiates transcription
c) Enzyme transcriptase is involved
d) A message from DNA to ribosome

2. Write detailed answers of the following questions:

i) What are chromosome? Give their chemical composition and ultra structure.
ii) Prove with help of experiment that DNA is the hereditary material.
iii) Discuss Watson and Crick model of DNA and its replication.

3. Write short answers of the following questions :

i) What do you mean by karyotypes?
ii) What are autosomes and sex chromosome?
Iii) Define chromosome and its type.
iv) What is chromosomal theory of heredity?
v) Name the components of nucleotides of hereditary material?
vi) What is mutation?
vii) What is transcription?
viii) What do you know about sickle cell anemia?
ix) What is Phenylketonuria?

4. Define the following terms :

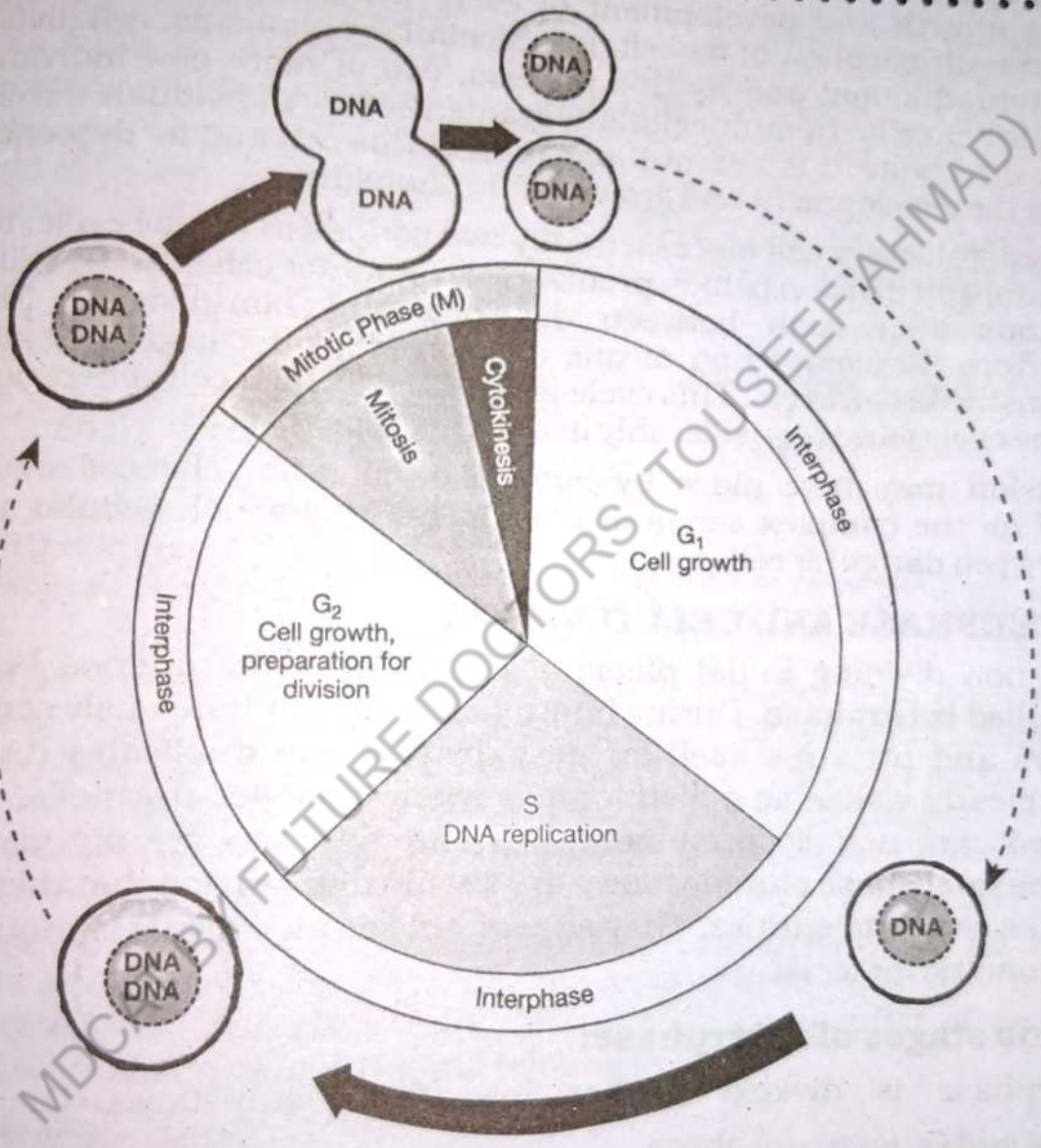
i) Nucleosome
ii) Genome
iii) Tanscription
Iv) Translocation

5. Distinguish between the following:

i) DNA and RNA
ii) Transcription and translocation

CHAPTER 7

CELL CYCLE



"All cells come from cells". With these words, **Rudolf Virchow** captured the crucial importance of cellular reproduction for both unicellular and multicellular organism. All cells are descended from pre-existing cells, cellular reproduction is absolutely essential for continue existence of life on earth. Cell reproduce by division process, form daughter cells. Each daughter cell also inherits about half of the parent's cell cytoplasm; including full complement of organelles. Each round of growth and cell-division is called a **cell cycle**.

It is a natural question what makes the cell divide or why the reproducing cells stop dividing. If we take a unicellular organism, for example *Amoeba*, it is seen that it feeds, grows and attains a certain size; afterwards it divides. On the other hand if *Amoeba* is starved, it shrinks and stops dividing. Therefore, it appears as if the cell division is a way to keep a constant ratio between the amount of cytoplasm and nucleus. It means that the division of cell is regulated by the amount of nucleoplasm. This can be explained by the fact that the nucleus governs the activities of cell and can efficiently control only over a certain amount of cytoplasm. Hence, the growth and development of every living organism depends on the growth and multiplication of its cell. In unicellular organisms, cell division is the means of reproduction, and by this process, two or more new individuals arise from the mother cells. In multicellular organisms, new individuals develop from a single cell, the zygote; it is the multiplication of this cell and its descendants that determines the development and growth of the individual.

In general, every cell has essentially two periods in the life cycle; interphase (non-division) and division (which produce two daughter cells). Many cells undergo a continuous alternation between divisions and non-division. The events occurring from the completion of one division until the beginning of the next division constitute cell cycle. This cycle is repeated at each cell generation, but the length of the cycle varies considerably in different types of cells.

Division may take place by mitosis or meiosis. The cell cycle can be considered as the complex series of phenomenon by which cellular material is divided between daughter cells.

7.1 INTERPHASE AND CELL DIVISION

The non dividing initial phase of the cycle as the interval between two divisions called **interphase**. During interphase, cell simultaneously carries out its work, grows and prepares itself for next division and duplicates its DNA. The nucleus is clearly visible as a distinct membrane-bounded organelle, and one or more nucleoli are usually prominent, but chromosomes are not visible in the nucleus. The interphase chromosomes are so thin and tangled that they cannot be recognized as separate entities. They appear only as an irregular granular looking mass of chromatic material.

7.1.1 3- Sub stages of interphase:

Interphase is divided further into three sub-stages G_1 (gap one), S (synthesis) and G_2 (gap two) phase.

G_1 is phase of interphase where no DNA synthesis occurs. During this G_1 phase synthesis and organization of substrate (RNA) and formation of enzymes required to DNA synthesis occur. It is most variable in duration and takes about 25 to 50% of the interphase. The G_1 period is of great interest in study of cell division and its control. At a point late in G_1, a cell follows one of two paths, either it withdraws from the cycle and enters a resting phase or G_o stage or enters into S phase to complete the cycle. Cells that enter G_o remain viable and metabolically active but do not divide.

S-phase is designated as synthesis stage because during S-phase DNA synthesis takes place and DNA content of the nucleus gets doubled. This phase is relatively of constant duration in case of similar cells of a species. Its duration is about 35 to 40% of the interphase time. The S-sub-stage is followed by G_2 sub-stage.

During G_1 sub-stage chromosomes are generally observed as single-stranded structures while in G_2 sub-stage they become double stranded, possessing two chromatids each. By the end of G_2 the volume of cell has roughly doubled, DNA has been replicated and mitosis (M) is initiated.

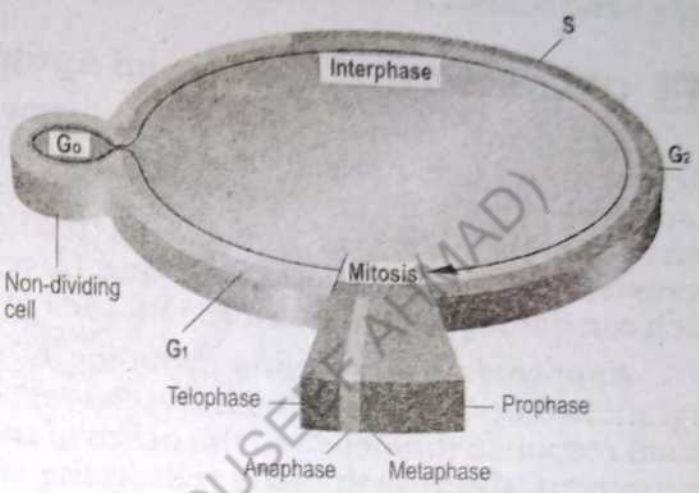


Fig 7.1 The eukaryotic cell cycle

The duration of the complete cell cycle can vary greatly. Though usually lasting 10-30 hours in plants and 18-24 hours in animals, it may be as short as 20 minutes or as long as several days or even weeks.

Of the various periods of the cell cycle the G_1 period is the most variable, in most eukaryotic cells, it lasts a minimum of three to four hours. Depending on the physiological conditions of the cells, it may last days; months, or years. The S and G_2 periods on the contrary are relatively constant. In most cells DNA synthesis takes place in seven to eight hours and G_2 period lasts two to five hours, where-as the period of mitosis requires only about one hour.

After completion of interphase cell division (mitosis-M) is a dynamic period of vigorous and continual activity. For the sake of study it is also further divided into 4 phases with specific events. These stages, in order of occurrence are prophase, metaphase, anaphase and telophase.

7.1.2 Cell divisions:

The next phase is mitotic phase (M-phase) in which a mature cell splits into two daughter cells. The division of a cell is achieved by two integral activities such as the division of nucleus (karyokinesis) and the division of the cytoplasm (cytokinesis). Usually the karyokinesis is followed by cytokinesis.

Following are the two main types of cell division, called **mitosis** and **meiosis**. To this we may add **amitosis**.

7.1.3 Amitotic cell-division of Prokaryotes:

A division without the formation of spindle is called **amitosis**. In amitosis the nucleus develops a constriction in the middle that finally divides it into two daughter nuclei. The cytoplasm may or may not be divided in a similar manner.

When the nuclear portions are unequal in size, the process is generally called **nuclear budding**. When the nuclear portions are more than two in number, the phenomenon is referred to as **nuclear fragmentation**. This kind of cell division occurs mainly in bacteria, old tissues, abnormal and diseased tissues such as cancer and tumor.

7.2 CELL DEATH (Necrosis and Apoptosis)

Cell death in multicellular organisms is controlled by two fundamentally different ways i.e. either cell carry out self destruction (Autophagy) in the absence of survival signals or cells are may be killed due to injury. In contrast to self destruction the death of living cells that result from tissue injury is called **necrosis**, during which cell swells and bursts, releasing the intracellular toxins, which can damage neighbouring cells and cause inflammation.

Apoptosis (Gr. means dropping of or falling off) is a type of orderly or programmed cell death in which the cell responds to certain signals by initiating a normal response that leads to the death of the cell. For example during embryonic development, the growth of the cells in the spaces between the fingers that are no longer needed; undergo apoptosis.

Apoptosis is thought to require the activation of a specific set of genes that have evolved to destroy the cell in a way that has the least effect on its neighbouring cells. Death by apoptosis is characterized by over all compaction of the cell and its nucleus, by the orderly dissection of the chromatin by special DNA splitting endonuclease and the rapid engulfment of the dying cells by phagocytosis.

Apoptosis is a common occurrence during embryonic development, but it also occurs in adult tissues and may be a particularly important weapon in the destruction of cells that have the potential to develop into malignant tumor.

Apoptosis appears to be mediated primarily by the release of Ca^{++} and the activation of certain proteins-kineses and required activation of a specific set of gene.

7.3 MITOSIS

The mitotic cell cycle consists of interphase and mitosis. The process of cell division called mitosis is more or less similar both in plants and animals. It takes place during embryonic development and growth. It is also necessary to replace cells that wear out, e.g. blood cells, skin cells, intestinal lining etc. The process of mitosis is very regular, divisible in four stages; **Prophase**, **Metaphase**, **Anaphase**, and **Telophase**. It is in fact a continuous process during which one phase passes into the other. As a net result of mitosis the nucleus divides to form two daughter nuclei (karyokinesis) and the cytoplasm also divides to give rise to two daughter cells (cytokinesis), which is not a part of mitosis but necessary for complete division of the cell.

Prophase:

As the prophase starts, the chromatin network breaks up to form long coiled threads called chromosomes. Later in prophase the chromosomes shorten and thicken. Each chromosome is in fact a pair of fine threads, called chromatids lying so close that an individual chromatid cannot be distinguished at this stage. The

two chromatids of each chromosome are held together at centromere which is visible as a circular achromatic zone in each chromosome.

During prophase the nuclear envelope breaks down, and a network of microtubules called the spindle apparatus forms between opposite poles of the cell. The position of the spindle apparatus determines the plane in which the cell will divide.

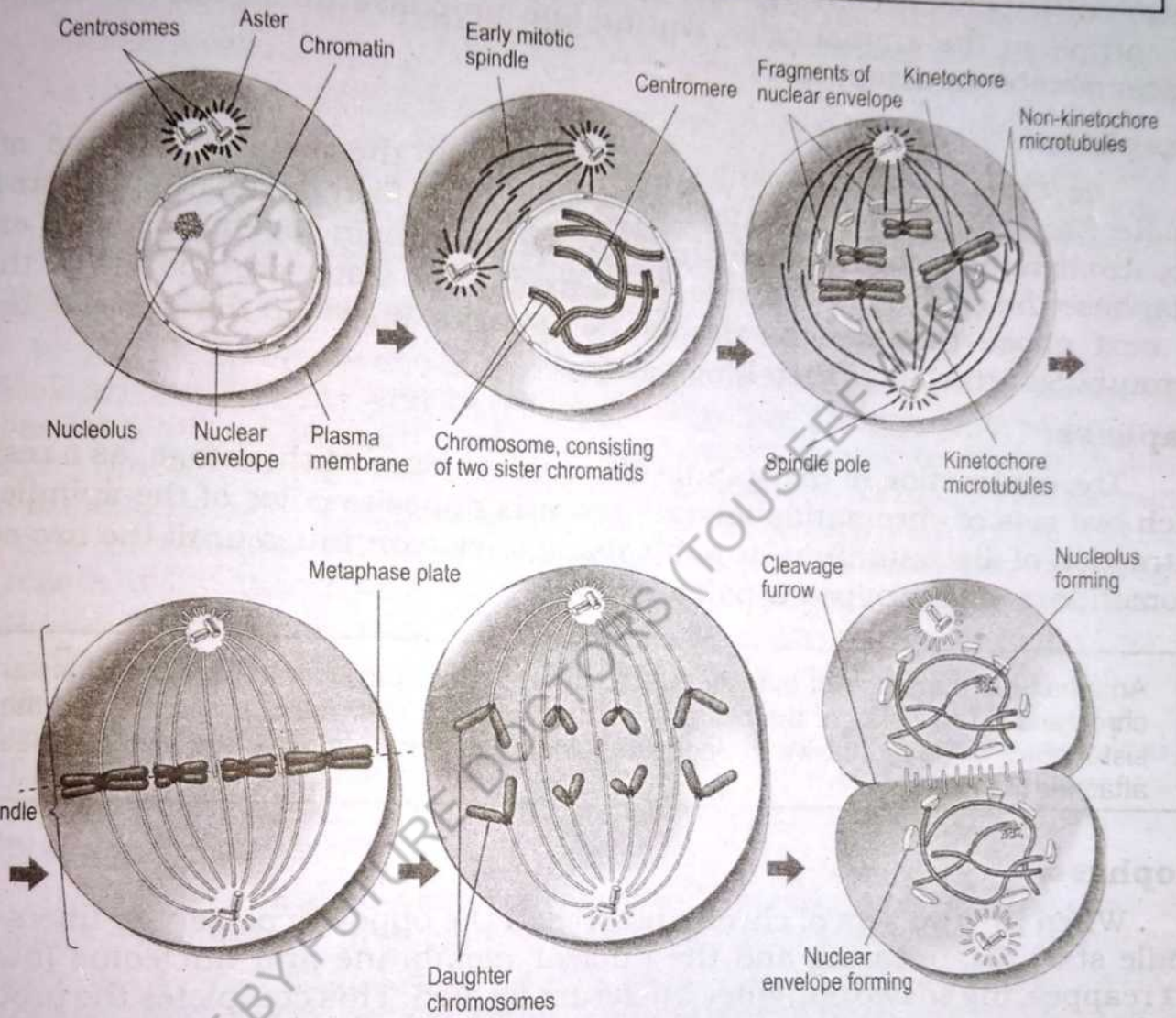


Fig 7.2 Different stages of Mitosis

During early prophase chromosomes are uniformly distributed in the nucleus. As the prophase progresses, the chromosomes move to the peripheral part, near the nuclear membrane and the central part of the nucleus becomes empty. There is maximum shortening of the chromosomes. Another development taking place during prophase is the appearance of spindle fibers outside the nucleus. Their formation varies in some animal and plant cells. In most of the animal cells, one or two rod like structures called centrioles lie in the cytoplasm near the nucleus, it divides into two, one set remain at its place and the other one moves to the opposite pole. As the centrioles get apart, very fine fibers appear in between and around them. Ultimately a structure is formed in the cytoplasm, which is called mitotic apparatus. This apparatus contains three types of fibers:

i) Continuous spindle fibers; running from pole to pole.
ii) Half or discontinuous spindle fibers; running from pole to equator.
iii) Astral fibers; short fibers radiating from the centrioles only at poles

Higher plants and some insects lack the centriole. In them the spindle appears with its fibers converging to pole regions comparable to the area occupied by centriole in the animal cells. During late prophase nucleolus (nucleoli) and nuclear membrane disappear.

Metaphase:

The chromosomes arrange them selves at the equatorial plane of the spindle. Each chromosome is attached to the spindle fiber by the Kinetochore (part of centromere). Up to this time the chromatids remain together. At the end of metaphase the centromeres divide, thus freeing the sister chromatids so that in the next phase they can be drawn to opposite poles of the spindle by the microtubules attached to their kinetochore.

Anaphase:

The contraction of the spindle fibers takes place at this stage, as a result of which two sets of chromatids migrate towards opposite poles of the spindle. The contraction of discontinuous or half spindle fibers continues until the two sets of chromatids reach the opposite poles.

> Anaphase is the stage of mitosis characterized by the physical separation of sister chromatids. The poles of the cell are pushed apart by microtubular sliding, and the sister chromatids are drawn to opposite poles by the shortening of the microtubules attached to them.

Telophase:

When the two sets of chromatids reach the opposite poles, the fibers of the spindle start disappearing and the nuclear membrane and nucleolus (nucleoli) start reappearing so two daughter nuclei are formed. This completes the process of karyokinesis.

> Telophase is the stage of mitosis during which the mitotic apparatus assembled during prophase is disassembled, the nuclear envelope is reestablished, and the normal use of the genes present in the chromosomes is reinitiated.

Cytokinesis:

Karyokinesis is followed by cytokinesis. In animal cell a constriction or depression appears in the cytoplasm from outside and goes on increasing towards inner side until it completely divides the cytoplasm. In plants the cytokinesis takes place with the appearance of cell plate at the equatorial plane which moves side ways to divide the mother cell into two daughter cells.

In animals, the mitosis is **amphi-astral**, where an aster is formed at each pole of the spindle but in plant cells, the mitosis is **an-astral**, where no aster is formed.

Significance of mitosis:

i) The process of mitosis provides a means to develop from zygote stage to adult stage and further growth during life. By simple mitotic division new cells are made available to the body for the formation of tissues and organs.

ii) In some tissues, e.g. red blood cells, in the bone marrow, the wear and tear of old cells is so rapid that mitosis must take place with speed to replace the worn-out cells.

iii) As the millions of cells in the body are product of mitotic division of original zygote, each cell contains the same diploid number of the same kind of chromosomes. In this way, the mitosis results in equal quantitative and qualitative distribution of the chromosomes, together with the hereditary material to the daughter cells that are produced by mitosis.

7.3.1 Cancer as a result of uncontrolled Cell-Division:

In 1908 Wilson, described how living sponges were forced to dis-aggregate into isolated motile cells and then, upon standing re-aggregate to form fresh sponges. Much later it was found that embryonic tissues treated with trypsin dissociate into individual cells, and then re-aggregate to form the specific pattern of the original tissues. The process of re-aggregation depends on the motility of cells, and intercellular coupling. Some cells show no intercellular coupling but may regain it by fusion with normal cells. Experiments have shown that cell dissociation and re-aggregation of cells of a given tissue recognize each other. But when cells show no intercellular coupling or could not re-aggregate and do not show inhibition of cell motility and also of mitotic activity as in normal cells, such cells become cancerous. In these, cancer cells the mitotic rate is not inhibited and the cells tend to pile up amitotically, forming irregular masses several layers deep. These cells show less adhesion to the solid support or among themselves and motility is more pronounced.

The cancer cells are developed by mutation of cellular genes that control cell growth and cell mitotis. Thus, chance alone is all that is required for mutations to take place, so we may suppose that a very large number of cancers are merely the result of an unlucky occurrence. Yet, the probability of mutation can be increased when a person is exposed to certain chemicals, physical or biological factors such as ionizing radiation, X-Rays, gamma rays and radiations from radioactive substances and even ultra violet light. In many families there is a strong hereditary tendency to develop cancer.

In animals, certain types of viruses can cause some kinds of cancer, including leukemia. In this case, the DNA strand of the virus can insert itself directly into one of the chromosomes and there by cause the mutation that leads to cancer.

Why does Cancer cells kill?

The cancer tissues compete with normal tissues for nutrients. Because cancer cells continue to divide indefinitely, their number multiply day by day,

hence, these cells demand essentially all the nutrition available to the body. As a result, the normal tissues gradually suffer nutritive death.

7.4 MEIOSIS

Meiosis or reduction division is a special and prolonged type of cell division occurring in the reproduction of germ cells. The process of meiosis occurs both in plants and animals.

In animals it occurs during gametes formation whereas in plants, it occurs during spores formation. It has already been stated that every species of animals and plants has a definite number of chromosomes and that this number remains constant in its somatic cells, generation after generation. To keep the number constant, the chromosome number in gametes is reduced to half. When male and female gametes and their nuclei fuse, the normal number of chromosomes characteristic of each species is restored. The somatic or vegetative cells having the complete number of chromosomes are called diploid (2n). While gametes containing half of the original number of chromosomes are called haploid (n) or monoploid.

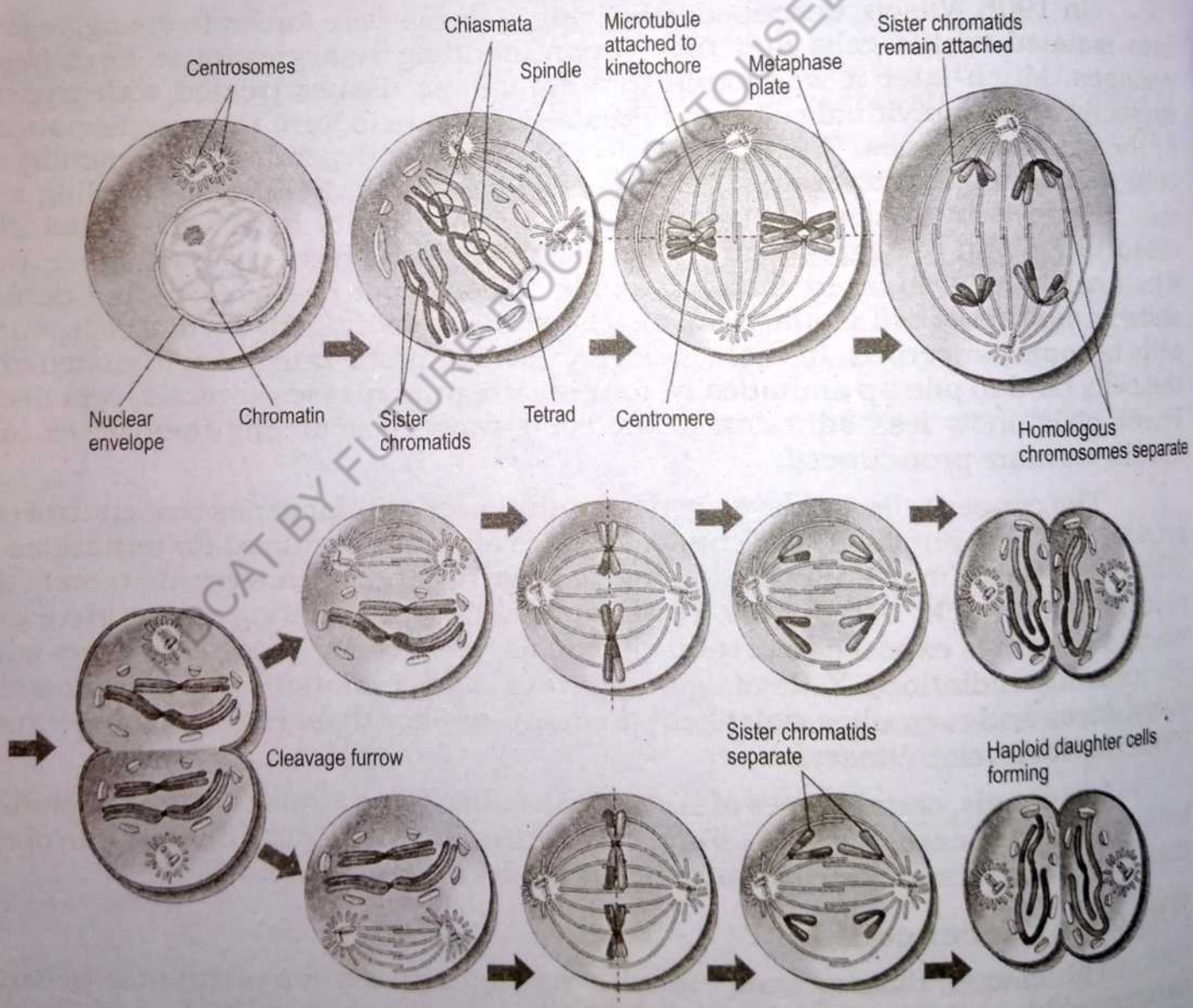


Fig 7.3 Different stages of Meiosis

Two important properties distinguish meiosis from mitosis:
> In meiosis the homologous chromosomes pair lengthwise, and their chromatids exchange genetic material by crossing-over.
> The sister chromatids, which are not identical after crossing-over, do not separate from one another in the first nuclear division, and the chromosomes do not replicate between the two nuclear divisions

The events of Meiosis:

Meiosis consists of two successive divisions of a mother cell. The first division is the reduction division, during which the chromosome number (2n) in both daughter cells is reduced to half (n), the second division is simple mitotic division resulting in four cells, each having the same reduced number (n) of chromosomes.

Both, first and second divisions are divisible into four stages known as: Prophase I Metaphase I, Anaphase I, and Telophase I in the first meiotic division, and Prophase II, Metaphase II, Anaphase II, and Telophase II in the second meiotic division.

First meiotic division:

Prophase I:

The prophase of the first meiotic division is longer in duration and significantly modified in comparison to the mitotic prophase. The following five sub-stages are recognizable in prophase I:

i) Leptotene ii) Zygotene iii) Pachytene
iv) Diplotene v) Diakinesis

i) Leptotene: The leptotene initiates meiosis. The cell undergoing meiosis is comparatively large in size and possesses a large nucleus. It has diploid chromosome number. The chromosomes or choromonemata in this stage are observed to be thin, long threads and longitudinally single rather than double as in mitosis. Each chromosome presents beaded appearance due to the presence of dense granules of chromomeres at irregular intervals along its entire length.

ii) Zygotene: The zygotene commences with the movement of homologus chromosomes brought together by the attraction between them. Thus the chromosomes of each homologous pair approach each other and become intimately associated to form a **bivalent**. The pairing of homologous chromosomes is known as **synapsis**. It starts at one or more points along the length of chromosomes and the chromomere of one homologue synapse exactly with the corresponding one of the other. The nucleus now appears to have half the number of chromosomes.

Synapsis is the close pairing of homologous chromosomes that takes place early in prophase I of meiosis. During synapsis, the DNA molecules of the two homologous chromosomes are aligned side by side. As a result, a DNA strand of one homologue can pair with the corresponding DNA strand of the other.

iii) Pachytene: During this stage the paired chromosomes of the each bivalent get shortened and thickened and are more readily distinguishable. The homologous chromosomes twine around each other and each starts splitting into two sister chromotids by a longitudinal splitting each pair forming four chromatids called **tetrads**.

iv) Diplotene: In this stage, the synaptic forces of attraction between each bivalent consisting of four chromatids, lapse and the chromosomes uncoil and separate. The separation is, however, incomplete and paired chromosomes are in contact with each other at one or more points. These points of contact are known as **chiasmata**. Exchange of chromatid parts takes place between paired chromosomes due to the breakage and rejoining of segments of chromatids at chiasmata. This is known as **crossing over**. The important thing to keep in mind is that whole blocks of genes are transferred between non-sister chromatids of a tetrad during crossing over.

v) Diakinesis: The diakinesis is characterized by the disappearance of the nuclear membrane, nucleolus and completion of spindle apparatus. The separation of bivalents is completed by the process called **terminalization**, in which the movement of the chiasmata from the centromere towards the ends of the chromosome arms takes place like a zipper, and at the end of diakinesis the two chromatids are held together only at their ends. Now the bivalents become more thickened, contracted and prominently visible. Prophase I ends here.

Metaphase I:

The bivalents now line up at the equatorial plane. The tetrads then attach themselves to the half spindle fibers at the centromeres. Each chromosome of the bivalent becomes connected to the half spindle fibers of one pole and the other half with the half spindle fibers of the opposite pole.

Anaphase I:

In this stage, each chromosome of the bivalent of homologues is pulled towards the opposite pole by the contraction of the half spindle fibers. The anaphase is completed when the two sets of chromosomes reach the opposite poles of the cell.

> The random orientation of homologous chromosome pairs on the metaphase plate and the subsequent separation of homologues from one another in anaphase are responsible for the independent assortment of traits located on different chromosomes.

Telophase I:

When the chromosomes reach opposite poles, two new nuclei begin to form. New nuclear membranes appear and the chromosomes uncoil. A brief pause in the meiotic process may follow. However, the chromosomes are still double stranded (consist of two chromatids) thus they are ready to divide again and the second meiotic division begins.

Second Meiotic division:

The telophase I, is followed by a short interphase which corresponds with mitotic interphase. Sometimes the interphase may persist for a considerable

length of time. At the interphase between the two meiotic divisions there is no replication of chromosomes. These are now haploid in number althought each one consists of two chromatids.

Prophase II:

The centrioles divide and the spindles are formed which are at right angles to the spindle of the first meiotic division. The nuclear membrane disappears and the splitted chromosomes (diads) arrange themselves at the equatorial plane.

Metaphase II:

The half or discontinuous spindle fibers attach at the centromeres of the diads and the two chromatids get separated at the centromere from each other.

Anaphase II:

Movement of two sets of chromatids at each spindle starts towards the opposites poles. Each chromatid is now called **monad**. The anaphase finishes when the monads reach the poles.

Telophase II:

The chromosomes uncoil and form separate groups and around each group a nuclear membrane is formed. Cytoplasmic division or cytokinesis is followed resulting in four daughter cells, each with haploid number of chromosomes.

> Sexual reproduction and the close association between homologous chromosomes that occurs during meiosis probably evolved as mechanisms to repair chromosomal damage by using the homologous chromosome as a template. This repair mechanism then provided a ready means for generating genetic recombination by crossing-over.

Significance of meiosis:

i) Meiosis is a logical and necessary part in the life cycle of sexually reproducing animals and plants, as it helps in restoring the definite number of chromosomes. As a result of meiosis the gametes are formed, each gamete possesses haploid (n) number of chromosomes and the fusion of gametes at the time of fertilization results in the diploid (2n) number. Thus meiosis helps in the maintenance of chromosomal number in species generation after generation. In the absence of meiosis, number of chromosomes would have been doubled giving rise to abnormal growth, changes in species characteristics and at the same time may prove fatal.

ii) During the process of meiosis crossing over takes place between the two homologous chromosomes. The crossing over and chiasmata formation result in exchange of chromosome pieces between the two homologues. Thus, new combinations of genetic materials are facilitated which lead to the evolution of the new forms.

7.4.1 Meiotic errors:

In normal course of meiosis the two chromsomes of each homologous pair separate out and enter two separate cells, the gametes. But, sometimes the

members of the pair fail to separate, resulting in the formation of abnormal daughter cells, one having both the chromosomes of a pair whereas the other one lacks the chromosome pair. This failure in the separation of the homologous chromosomes due to meiotic error is known as **non-disjunction**, which results in abnormal chromosome number.

A change in the normal chromosome number is called **heteroploidy**. Most animals have two of each kind of chromosomes but some species have more than two of every homologous chromosome. This condition is called **polyploidy**. Usually 'n' represents monoploid condition of homologous chromosome number, '2n' diploid condition, '3n' triploid and '4n' tetraploid condition. Polyploidy is common in plants but is rare in animals. The number of one or more chromosomes may change during the formation of new individual. Such a change in an individual is called an **aneuploid** in which chromosomes may be added or subtracted.

Human defects disorders due to abnormal number of chromosomes:

Down's Syndrome (Trisomy 21):

The most common type of human abnormality, 'aneuploid' is Down syndrome or Mongolism. It was discovered that mongoloid has an extra chomosome attached to pair 21. One out of every 900 births show Down syndrome.

It is a maternal age defect for Down's Syndrome; Older mothers show greatly increased risk of having Down syndrome children. The abnormalities of this disease include mental retardation, with low IQ in 20-50 range, broad flat face, eyes with folds, short stature, short hands and large tongue. Females may be fertile and may produce normal or trisomic progeny, but males never reproduce. Life span is about 17 years and only 8% can survive up to 40 or above.

Non-disjunction of sex chromosomes occur both in men and women. Non-disjunction in men produce sperms that are O (lacking any sex chromosome) or both XY instead of normal X or Y. In women non-disjunction produces O or XX eggs instead of normal X. When normal gametes fuse with these defective sperm or egg the zygotes have abnormal numbers of sex chromosomes. The most common abnormalities are XO, XXX, XXY and XYY. Genes on X-chromosomes are absolutely essential for survival, and embryos with no X-chromosomes always abort very early in development.

1. Klinefelter's Syndrome (XXY):

The combination of XXY one out of thousand males birth, results in Klinefelter's syndrome. It is because of one extra chromosome, i.e. 47 (2n+1) trisomic condition. At puberty, these men show mixed secondary sexual characteristics. For instance, the breasts develop but testes remain small with no sperm formation. They are always sterile.

2. Turner's Syndrome (XO):

In humans, a person with this syndrome has normal 44 autosomes + 1 sex chromosome. About 1 in every 5000 female babies has only one X chromosome. This female is easily recognizable; she is sterile, short in stature and has folds of skin around her neck and shoulders. Mentally they are usually normal except that

they are weak in mathematics and special perceptions (recognition of an object). This is monosomic condition since it lacks one chromosome.

KEY POINTS

- In unicellular organisms, cell division is the means of reproduction, and by this process, two or more new individuals arise from the mother cell.
- The non-dividing cell is said to be in the interphase stage.
- The cell cycle is exceptionally rapid during the first cleavages of the egg cell, the blastomeres divide without any intervening growth of the cell. In this case the S-period is very short and G_1 period may even be absent.
- A cell division without the formation of spindle is called amitosis.
- The process of cell division called mitosis is more or less similar both in plants and animals.
- As the prophase starts, the chromatin network breaks up to form long coiled threads called chromosomes.
- The process of mitosis provides a means for development and growth.
- Meiosis or reduction division occurs germ cells at the time of gamete formation.
- The anaphase is completed when the two sets of chromosomes reach the opposite poles of the cell.
- Meiosis helps in restoring the definite number of chromosomes characteristic of the species.

EXERCISE

1. Encircle the most correct choice:

i) At what stage of mitosis are chromosomes arranged along a plane at the midline of the cell?

a) Anaphase b) Telophase
c) Metaphase d) Interphase.

ii) A diploid cell contains in its nucleus.

a) an even number of choromosomes
b) an odd number of chromosomes
c) one copy of each homologues
d) either an even or an odd number of chromosome.

iii) Synthesis of new DNA occurs during

a) Prophase b) Interphase
c) Mitosis d) Cytokinesis

iv) Interphase consists of following sub-stages, the correct sequence is

a) G_1, G_2, S b) S, G_1, G_2
c) G_1, S, G_2 d) all of them.

v) Down's Syndrom is an example of:

a) Trisomic b) Monosomic → XO (Turner)
c) Nullisomic d) None of them

vi) A type of orderly or programmed cell-death

a) Necrosis b) Apoptosis
c) Synapsis d) Mitosis

vii) Meiotic prophase-I sub stage where terminalization takes place

a) Leptotene b) Pachytene
c) Diplotene d) Diakinesis

viii) Meiotic prophase-I sub stage where chiasmata are formed

a) Leptotene b) Pachytene
c) Diplotene d) Diakinesis

ix) In animals the mitosis is

a) Amphi- astral b) Anastral → in plants
c) Multi-astral d) No-astral

2. Write detailed answers of the following questions:

i) Describe and compare the process of mitosis in animal cells and compare it with plant cells.

ii) Draw and describe all the stages of meiotic division-I, prophase-I and compare it with prophase II.

iii) Draw the diagram and describe the Eukaryotic cell cycle. Name the various phases and briefly describe the events that occur during each.

3. Write short answers of the following questions :

i) What is an interphase stage during cell cycle?

Ii) What is G1 stage?

iii) What is S-stage?

iv) What is amitosis?

v) What is nuclear budding?

vi) What do you mean by necrosis and apoptosis.

vii) What is karyokinesis and cytokinesis.

viii) What is nuclear spindle?

4. Define following terms:

i) Mitosis

ii) Meiosis

iii) Mitotic apparatus

iv) A mitosis

v) Cytokinesis

vi) Chromosome

vii) Diploid stage

viii) Haploid stage

ix) Polyploidy

5. Distinguish between the following :

i) Prophase and telophase (mitosis)

ii) Meiotic metaphase and mitotic metaphase

iii) Klinefelter and Turner's syndrome

CHAPTER 8

VARIATION AND GENETICS

It was not until the year 1990 that biology finally caught up with Gregor Mendel. At that time, three botanists, working independently on plant breeding experiments, reproduced Mendel's results. By searching the literature, the German Karl Correns, the Austrian Erich von Tshermak, and the Dutchman Hugo de Vries all found that Mendel had explained the same results 35 years before. During the intervening years, biology had grown more experimental and quantitative and thus more receptive to Mendelism. Nevertheless, many biologists remained incredulous about Mendel's laws of segregation and independent assortment until evidence had mounted that these principles of heredity had a physical basis in the behavior of chromosomes. Mendel's hereditary factors-genes are located on chromosomes.

Every specie has a spectrum of heritable variation, and people have exploited this variation for centuries in developing domestic strains of plants and animals. These historical roots of genetics, "the scientific study of heredity and of the mechanisms by which characteristics are transmitted from one generation to the next dates back to the earliest attempts at selected breeding". In this chapter, we examine the rules that govern how inherited characteristics, are passed from parents to offspring and how variation occurs in the generations.

8.1 GENES AND ALLELES

GENES: Genes (Gr. genos = Birth, race) are the basic units of inheritance, consisting of a sequence of nucleotides that occupies a specific position called **locus** on a chromosome and is capable of a biological expression. It is the means by which one or more specific characteristics are passed on from parents to offspring.

ALLELES (Gr. allelon = of one another): Any of the possible alternative forms of the same gene, of which every individual inherits two (one from each parent), different combinations of which produce different characteristics.

8.1.1 Gene Pool:

The total aggregate of genes in a population at any one time is called the population's **gene pool**. It consists of all alleles at all gene loci in all individuals of the population. For a diploid species, each locus is represented twice in the genome of an individual, who may be either homozygous or heterozygous for those homologous loci. If all members of a population are homozygous for the same allele, that allele is said to be fixed in the gene pool. Usually however, there are two or more alleles for a gene, each having a relative frequency (proportion) in the gene pool.

An example will make more clear the concept of allele frequency more clear in a gene pool. Imagine a wildflower population with two varieties contrasting in flower colour. An allele for pink flowers, which we will symbolize by 'A', is completely dominant to an allele for white flowers, symbolized by 'a'. For our simplified situation, these are the only two alleles for this locus in the population. Suppose this imaginary population has 500 plants, and 20 of these plants have white flowers because they are homozygous for the recessive allele; their genotype is aa. The other 480 plants have pink flowers; 320 are homozygous (AA) and 160 are heterozygous (Aa). Because these are diploid organisms, there are a total of 1000 copies of genes for flower colour in the population of 500 individuals. The dominant allele (A) accounts for 800 of these genes (320 X 2 = 640 for 'AA' plants, plus 160 X 1 = 160 for Aa individuals). Thus, the frequency of the A allele in the gene pool of this population is 800/1000 = 0.8 = 80%. And because there are only two allelic forms of the gene, the a allele must have a frequency of 0.2, or 20%.

Related to these allele frequencies are the frequencies of genotypes. In our imaginary wildflower population, these frequencies are AA = 0.64 (320 out of 500 plants), Aa = 0.32 (160/500), and aa = 0.04 (20/500).

8.2 REVIEW OF MENDEL'S LAWS OF INHERITANCE

8.2.1 The work of Gregor Mendel:

Earlier investigators who had made hybridization experiments with plants were failed because of their methodology and choice of material. **Gregor John Mendel** was familiar with the work of his predecessors. The reason of his success lies in his wise choice of material and his methods of study.

1. Choice of experimental Material:

The element of luck in choice of experimental plant i.e. *Pisum sativum* (Garden pea) played a great role in the success of **Mendel**. This plant has following favourable characters.

i) The plants are easy to cultivate.

ii) This plant is self-pollinating and cross pollination can only takes place artificially.

iii) Artificial breeding is easy as flowers are comparatively large with numerous varieties are available with sharply defined contrasting characters, such as height of plant, seed surface, seed colour and colour of flower etc.

iv) Resulting hybrids are fertile.

v) He also avoided the complexities that had troubled the earlier worker.

2. Method of study:

Mendel started his studies by planting pea seeds with different characteristics and then crossing their flowers to see the pattern of inheritance of characters in the next generation. He studied the inheritance of such contrasting characters like green versus yellow seed colour and wrinkled versus smooth seed coat. He maintained a complete record of each cross and made exact counts of each type of offspring. Mendel found that the cross between green and yellow resulted in all yellow seed coats. He repeated this experiment with many strains of peas and came to the conclusion that when pea plants with two alternate expressions of the same character were crossed, one of the two appeared completely in the offspring, while the second did not show itself at all. He thus derived the **Law of dominance**. The character that was expressed in the first generation is called **dominant** and the contrasting character, which was not expressed called **recessive**. Similarly, Mendel discovered that in peas, the round seed coat character was dominant over the wrinkled, the red flowered over the white flowered and tall over the dwarf.

Mendel then proceeded to sow the hybrid pea seeds of the first generation (F_1 = First filial generation) and the resulting plants were allowed to self fertilize to produce seeds of the second generation (F_2). He found that in F_2 generation seeds of both yellow and green colours i.e. the dominant and the recessive appeared in the ratio of 3:1. He also discovered that whatever the character pair he studied, the ratio of plants with dominant character to those with recessive character was always close to 3:1 (Table. 8.1).

Table 8.1 Results of Mendel's monohybrid crosses.

	P_1 crosses	F_1	F_2	Ratios
1.	Tall X Dwarf stems	All tall	787 Tall 277 Dwarf 1064 Total	2.84 : 1
2.	Round X Wrinkled seeds	All round	5474 Round 1850 Wrinkled 7324 Total	2.96 : 1
3.	Yellow X Green cotyledons	All yellow	6022 Yellow 2001 Green 8023 Total	3.01 : 1
4.	Purple X White flowers	All purple	705 Coloured 224 White 929 Total	3.15 : 1
5.	Smooth X Constricted pods	All smooth	882 Smooth 299 Constricted 1181 Total	2.95 : 1
6.	Green X Yellow pods	All green	428 Green 152 Yellow 580 Total	2.82 : 1
7.	Axial X Terminal flowers	All axial	651 Axial 207 Terminal 858 Total	3.14 : 1

Mendel gave a generalized theoretical explanation of his results obtained from these experiments, which are now firmly established as Mendel's laws of inheritance. These are the **Law of Segregation** and the **Law of Independent Assortment**.

8.2.2 LAW OF SEGREGATION (Mendel's first law):

When pairs of contrasting characters are brought together in an individual they neither mix up nor affect each other. At the time of gamete formation the alleles for each contrasting character separate and pass into different gametes.

Thus each gamete contains only one allele of a particular character and is said to be pure. This separation of allele is called **law of segregation**. This law is also called **law of purity of gametes**.

Mendel's law of segregation: Each organism contains 2 factors for each trait and these factors segregate during the formation of gametes so that each gamete contains only one factor for each trait. When fertilization occurs, the new organism receives 2 factors for each trait, one from each parent.

8.2.3 Single trait inheritance:

The cross between two parents differing in one trait is called **monohybrid-cross** and the ratio obtained in F2 generation is called **monohybrid-ratio**. The result obtained from mono hybrid cross is spoken as **single trait inheritance**.

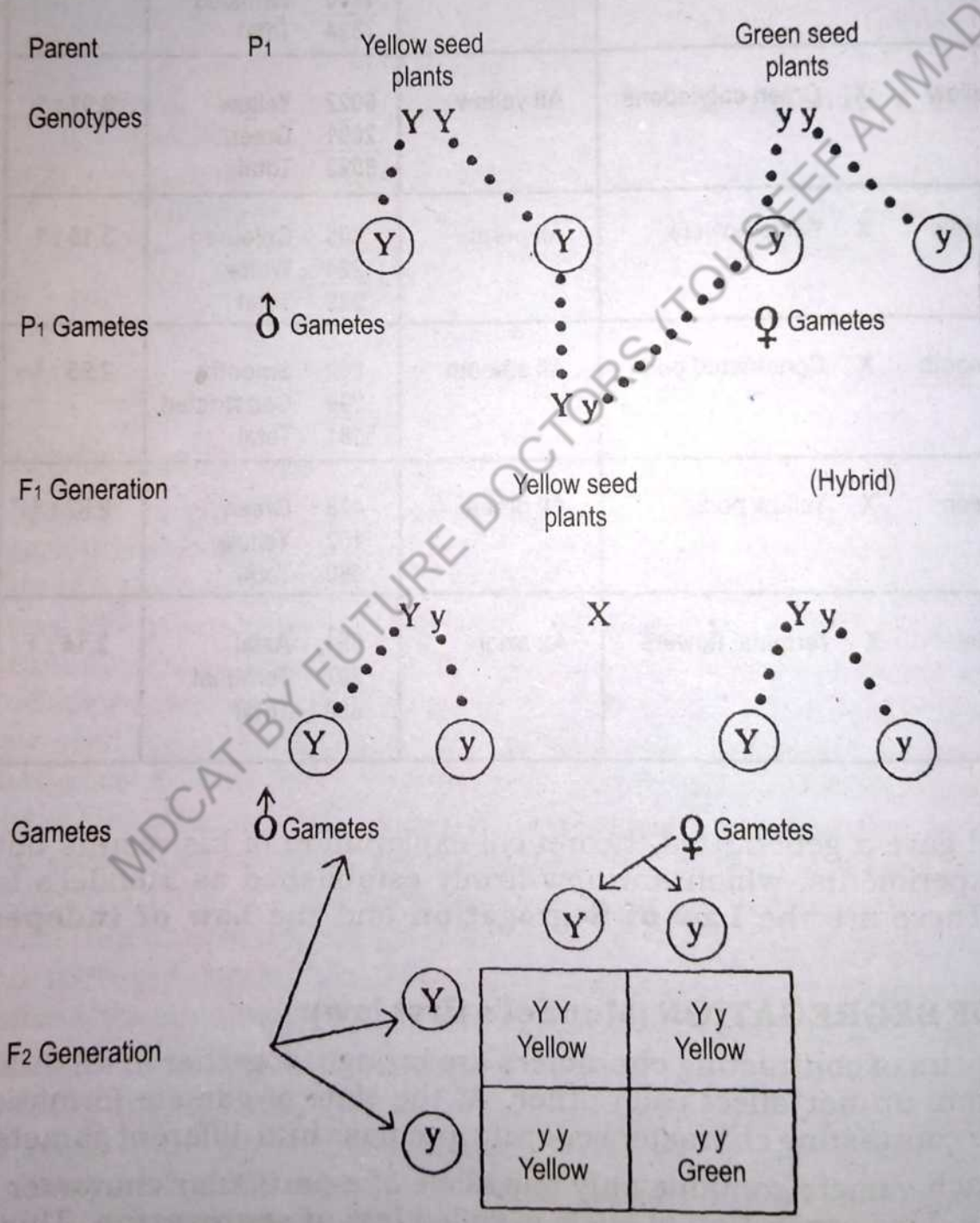


Fig 8.1 Monohybrid cross

8.2.4 Inheritance of two traits:

The cross between two individuals differing in two traits is called **dihybrid-cross** and the ratio obtained in F_2 generation is called **dihybrid-ratio**. The results achieved as a consequence of dihybrid-cross is spoken of as **inheritance of two traits.**

Mendel's experiments on garden peas were not limited to single character, but sometimes involved two or even more characters.

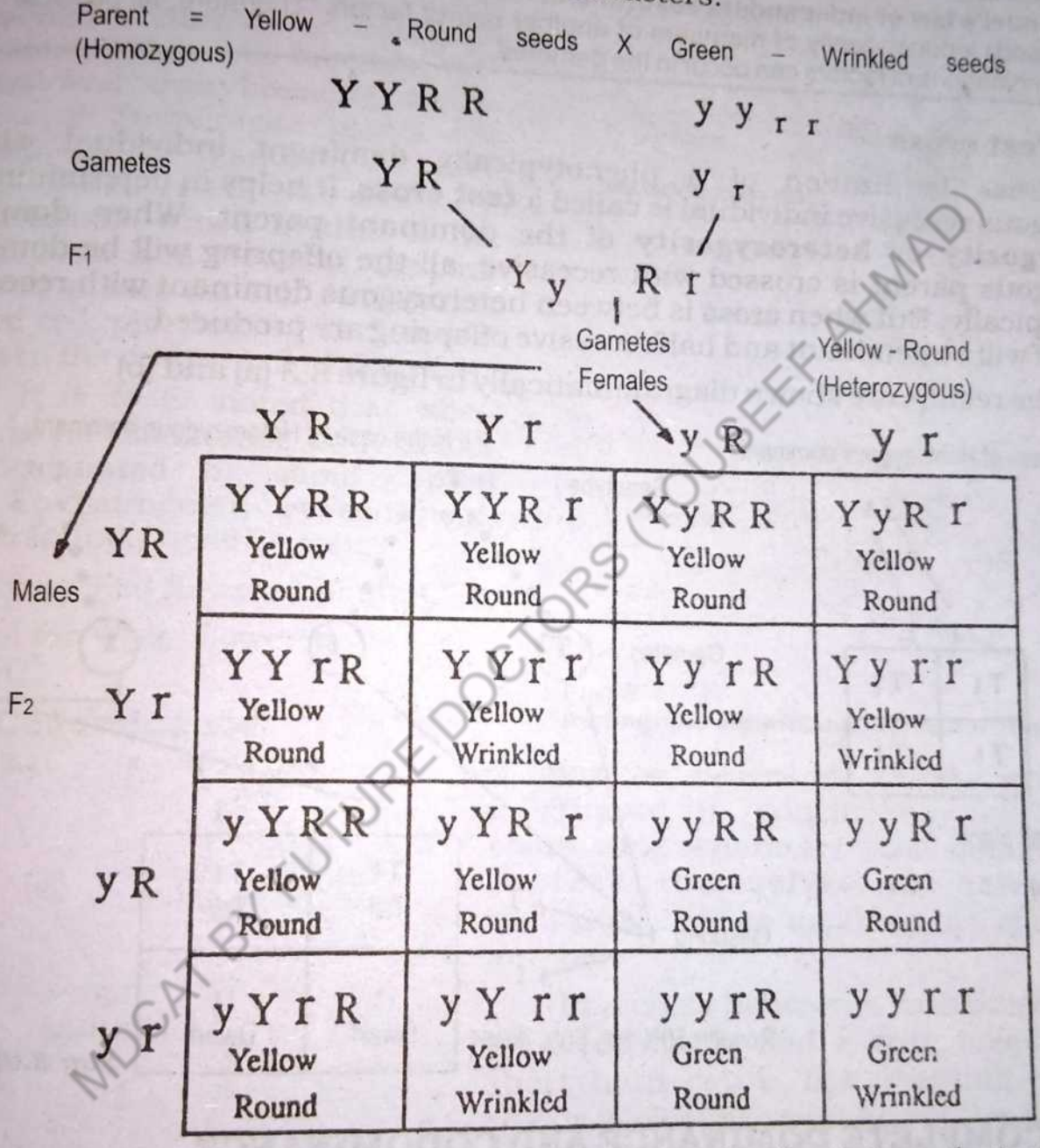


Fig 8.2 Inheritance of two pairs of characters in peas showing independent assortment

This experiment revealed that in crosses involving two traits (Dihybrid-cross) some phenotypically new plants, unlike either of the original parental plants, were produced. In other words, it demonstrated that the genes for seed colour and seed shape did not necessarily stay together in the combination in which they occurred in the parental generation. Instead they assorted independent of each other. This led to the formulating of a law called **Law of Independent Assortment,** which states that:

"The members of one pair of genes segregate independently of the other pairs".

Mendel found this true for all the combinations of the seven pairs of traits he used in his pea crosses. Yet, there are important exceptions and hence it is not a universal law.

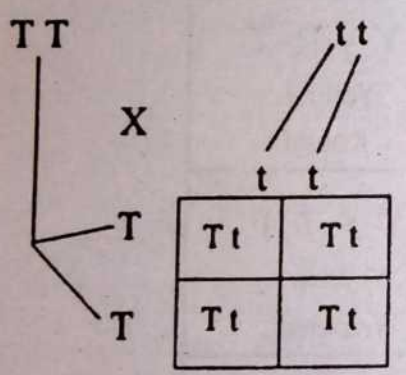
Mendel's law of independent assortment: Members of one pair of factor segregate (assort) independently of members of another pair of factors. Therefore, all possible combinations of factors can occur in the gametes.

8.2.5 Test cross

Cross fertilization of a phenotypically dominant individual with a homozygous recessive individual is called a **test cross**. It helps in determining the **homozygosity** or **heterozygosity** of the dominant parent. When dominant homozygous parent is crossed with recessive, all the offspring will be dominant phenotypically. But when cross is between heterozygous dominant with recessive, then half will be dominant and half recessive offspring are produced.

The results are shown diagrammatically in figure 8.3 (a) and (b)

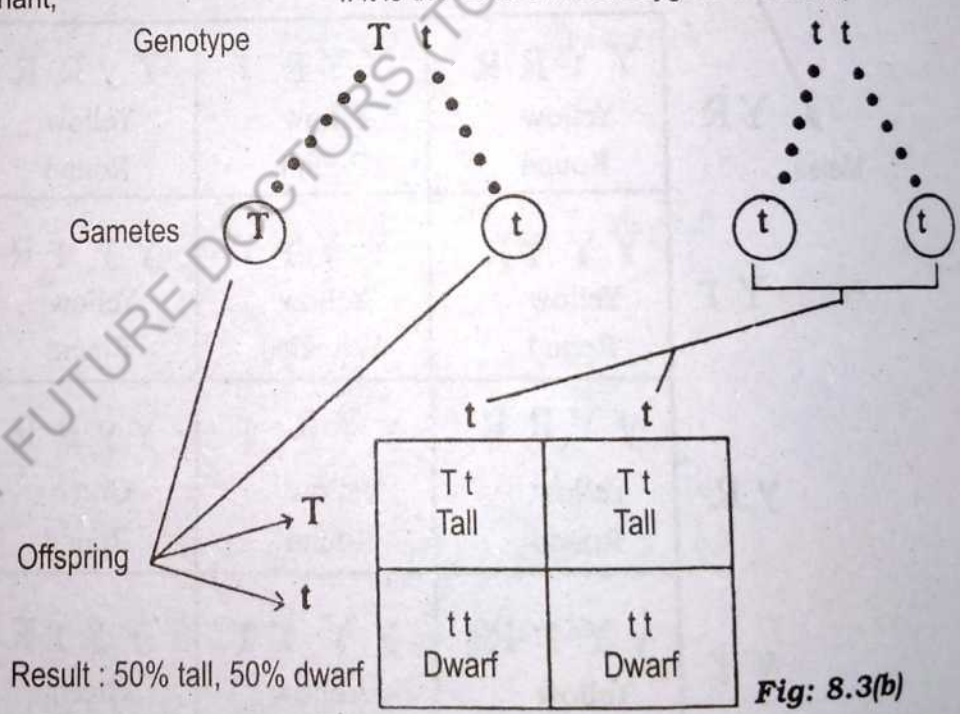
If it is the case of Homozygous dominant,



Result : All tall plant

Fig: 8.3(a)

If it is the case of Heterozygous dominant,



Result : 50% tall, 50% dwarf

Fig: 8.3(b)

8.3 INCOMPLETE DOMINANCE AND CODOMINANCE

8.3.1 Incomplete dominance:

The F_1 offspring of Mendel's classic pea crosses always looked like one of the two parental varieties because of the complete dominance of one allele over another. Many characteristics in a variety of organisms show this mode of inheritance. But many others do not. They may show another phenomenon of inheritance called **incomplete dominance** or intermediate inheritance.

It may be described as a phenomenon of inheritance in which dominant alleles of contrasting characters are not completely dominant over other resulting that heterozygous individuals have phenotypes in between the two contrasting characters or blending of characters occurs in heterozygous conditions. When true breeding red-flowers and true breeding white-flowers of Snapdragon plants are crossed, all the plants in F_1 carry pink coloured flowers a characteristic which neither of the parent possessed. However, the pink flowered plants on self fertilization yielded red, pink and white flowered plants in the ratio of 1 : 2 : 1 (Fig: 8.4)

It is to be noted that when there is no dominance both alleles are designated by same capital letter. To distinguish between them, a superscript is used hence:

Symbol for Red flowered plant=C^R

Symbol for White flowered plant=C^W

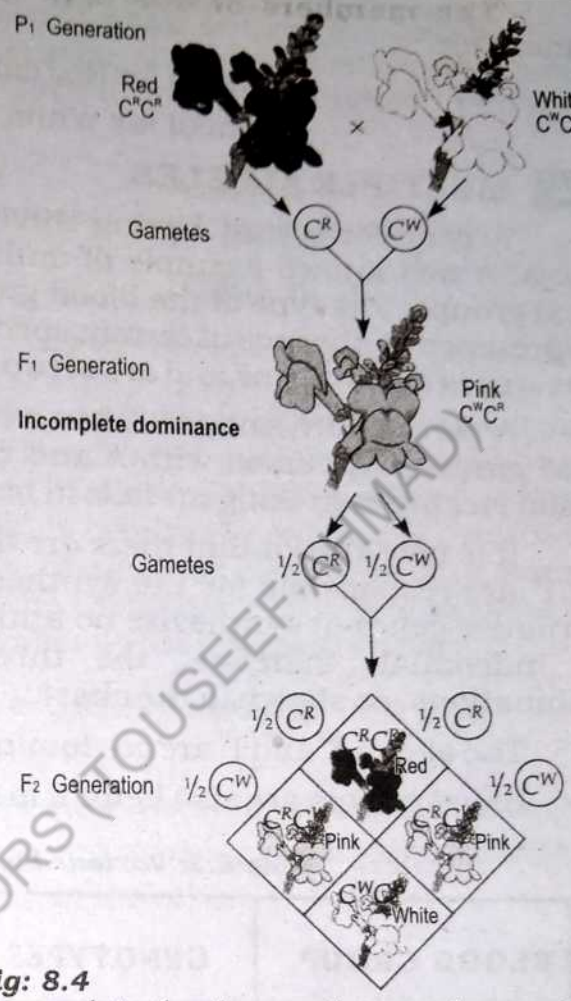


Fig: 8.4
Incomplete dominance in snapdragon flower

8.3.2Codominance:

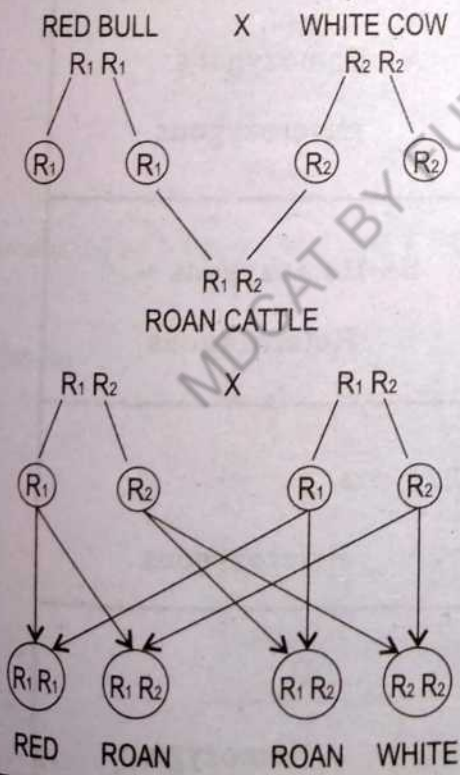


Fig: 8.5 Cross showing codominance

It may be described as phenomenon of inheritance in which both alleles of a contrasting character are dominant and express themselves in heterozygous individual neither masking the effect of one another.

In a cross between a true breeding short horn red cattle and a true breeding white short horn cattle, the offspring have roan colour. A close examination of the skin of roan coloured animal shows that the animal does not possess an intermediate shade of skin colour, but it appears so because of mixture of red hairs and white hairs. It is clear that none of the two genes is dominant over the other. Such pairs of alleles of a gene are said to be codominant and the phenomenon as codominance (Fig: 8.5).

Same procedure will be followed for symbols as in the case of incomplete dominance.

Symbol for Red cattle = R^1

Symbol for White cattle = R^2

8.4 MULTIPLE ALLELES

A gene for a trait having three or more allelic forms are called multiple alleles. A well known example of multiple alleles in human beings is that of the blood groups. The type of the blood group that a person may have, depends upon the presence or absence of certain specific substances in the red-blood cells. These substances are antigens and are of two kinds Antigen A and Antigen B.

A person with antigen A has a blood group A, and that with antigen B, has blood group B. A person with A and B antigens has blood-group AB. Similarly a person lacking both antigens falls in blood group O.

It is now known that there are three alleles responsible for this trait Gene I^A and I^B are responsible for the synthesis of antigens A and B respectively. Their alternative genes (i) synthesize no antigens at all. As only two alleles can occur in one individual, therefore, the three alleles can have only four possible combinations, as shown in the chart.

The alleles I^A and I^B are co-dominant and both are dominant over allele 'i'

Blood groups are also helpful in determining the paternity.

Table 8.2: Various blood-groups of Human beings

BLOOD GROUP	GENOTYPES	ANTIGEN	PHENOTYPES
Blood - Group A	$I^A I^A$	A	A Homozygous
	$I^A i$	A	Heterozygous
Blood - Group B	$I^B I^B$	B	B Homozygous
	$I^B i$	B	Heterozygous
Blood - Group AB	$I^A I^B$	A & B	A B Heterozygous
Blood - Group O	i i	No Antigen	O Homozygous

Blood types:

One of the genes is responsible for **Rhesus factor**. Antigen R is produced as a result of a dominant gene R whereas its recessive allele r does not produce any antigen. The possible genotypes and phenotypes in human beings in relation to this gene therefore can be:

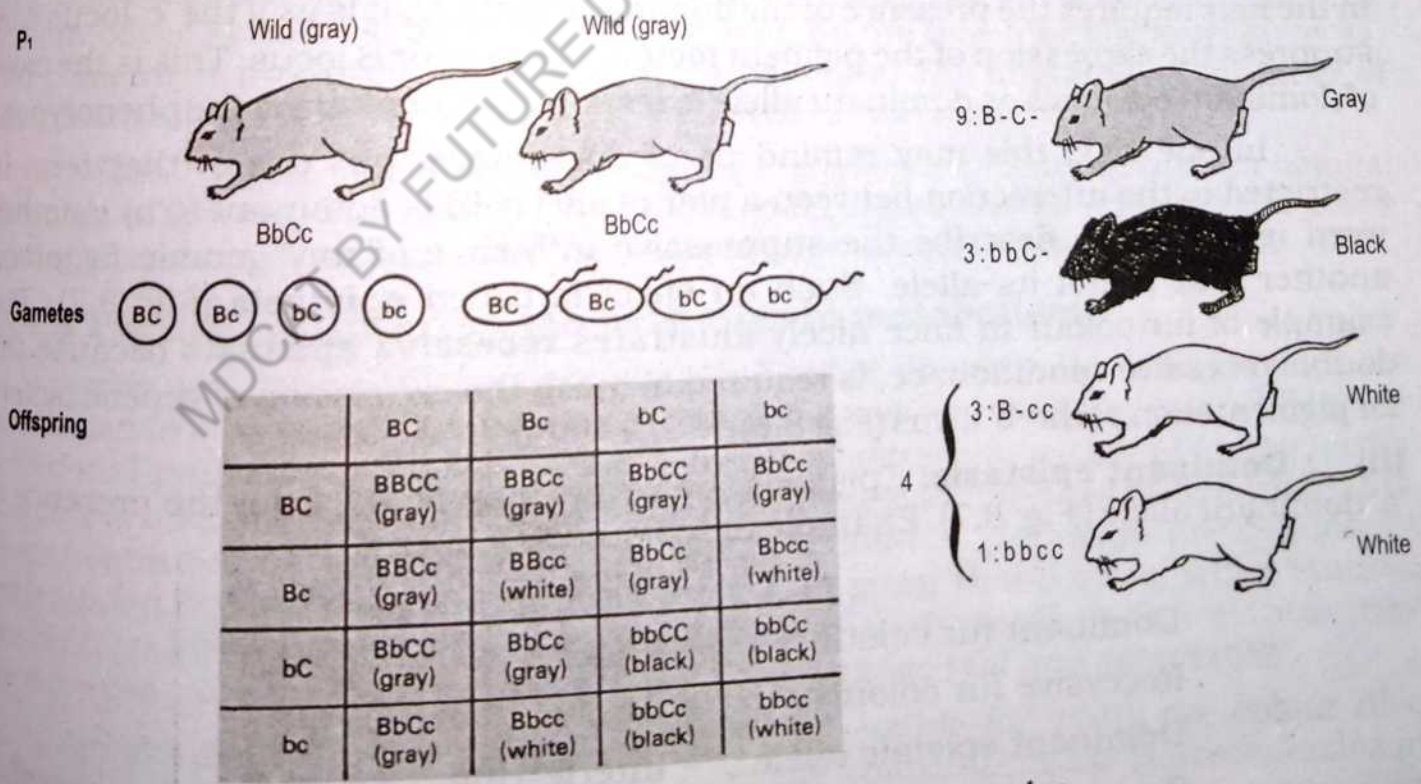
Phenotype	Genotype	Antigen
R^h +ve or R^h positive	$R^h R^h$, $R^h r^h$	R^h present
R^h -ve or R^h negative	$r^h r^h$	R^h absent

About 85% population is R^h positive. The knowledge about R^h factor is of particular importance in transfusion of blood and pregnancies. If an R^h negative woman marries an R^h positive man, her children are likely to be R^h positive, because R^h positive blood is a dominant genetic trait. Her first R^h positive child will trigger antibody production in her blood. Subsequent R^h positive children will be in danger of being born with **erythroblastosis foetalis**, in which the mother R^h antibodies invade the foetus and attack its red blood cells, causing the child to be born severely anaemic. Fortunately this condition can now be easily prevented by injections of a substance that prevents formation of Rh antibodies by the pregnant woman.

8.4.1 Epistasis (Genic interaction and modified ratios):

(Gr. Epi = on, stasis = a standing still)

A phenomenon in which one gene alters the expression of another gene that is independently inherited. On interaction between two monallelic genes in which one of them modifies the phenotypic expression of the other.



Offspring

	BC	Bc	bC	bc
BC	BBCC (gray)	BBCc (gray)	BbCC (gray)	BbCc (gray)
Bc	BBCc (gray)	BBcc (white)	BbCc (gray)	Bbcc (white)
bC	BbCC (gray)	BbCc (gray)	bbCC (black)	bbCc (black)
bc	BbCc (gray)	Bbcc (white)	bbCc (black)	bbcc (white)

Fig: 8.6 Cross of two dihybrid gray mice

Epistasis is a term that was coined before 1910 by **Bateson**. Once we understand the concept that many genes interact in the normal development of a character, we can appreciate the basis for various kinds of genetic effects respectively.

Epistasis may be due to recessive allels or dominant alleles of the epistatic genes and hence may be called **recessive epistasis** and **dominant epistasis**.

(i) Recessive epistasis: Let us take an example from the inheritance of fur colour in mice, in which more than one pair of alleles is known to influence pigmentation. In addition to the wild grayish colour, there are other possibilities, such as black or white.

Regarding these three types - grey , black, and white - two pairs of alleles are known to be involved. Wild gray, depends for its expression on the presence of a dominant, B; black pigmentation depends on the recessive allele, b. However, for any pigmentation at all, gray or black, to develop, the dominant allele, C, must be present at another separate locus. The recessive condition, cc, results in a white animal, regardless of the gene of any colour form present at the first locus.

Assume that two dihybrid animals are crossed: BbCc x BbCc (Fig:8.6). Both are wild in coat colour because each possesses the dominants for gray and for pigment production. Among their offspring, the following can be predicted: 9B–C- (gray): 3 bbC– (black): 3 B–cc (white): and 1 bb cc (white). Notice that these kinds of genotypes expected from a dihybrid cross are actually obtained; however, the expression of the genotypes is so altered by genic interaction that the expected phenotypic ratio of 9:3:3:1 is modified to a ratio of 9:3:4. This is so because the genotypes B–cc and bb cc cannot be distinguished from each other. Any pigment in the hair requires the presence of the dominant allele, C. It is as if the 'c' locus can suppress the expression of the pigment factors at the 'b' or B locus. This is the case of dominant epistasis as dominant allele is responsible for altering the phenotypes.

In one way, this may remind us of dominance, but use of that term is restricted to the interaction between a pair of alleles (B is dominant to b). Another word is needed to describe the suppressive influence of any genetic factor on another that is not its allele. Such an effect is called **epistasis** (Fig: 8.7). The example of fur colour in mice nicely illustrates **recessive epistasis** because the double recessive condition, cc, is required to mask the expression of genetic factors for pigmentation at the 'b' locus (Fig: 8.6).

(ii) Dominant epistasis: Epistasis, however, may result from the presence of 'a' dominant allele (Fig: 8.7). Example fur colour in Guinea pig.

Dominant fur colour	= Black	= B
Recessive fur colour	= Brown	= b
Dominant epistaic allele	= Interferring	= I
Recessive epistaic allele	= Non-interferring	= i

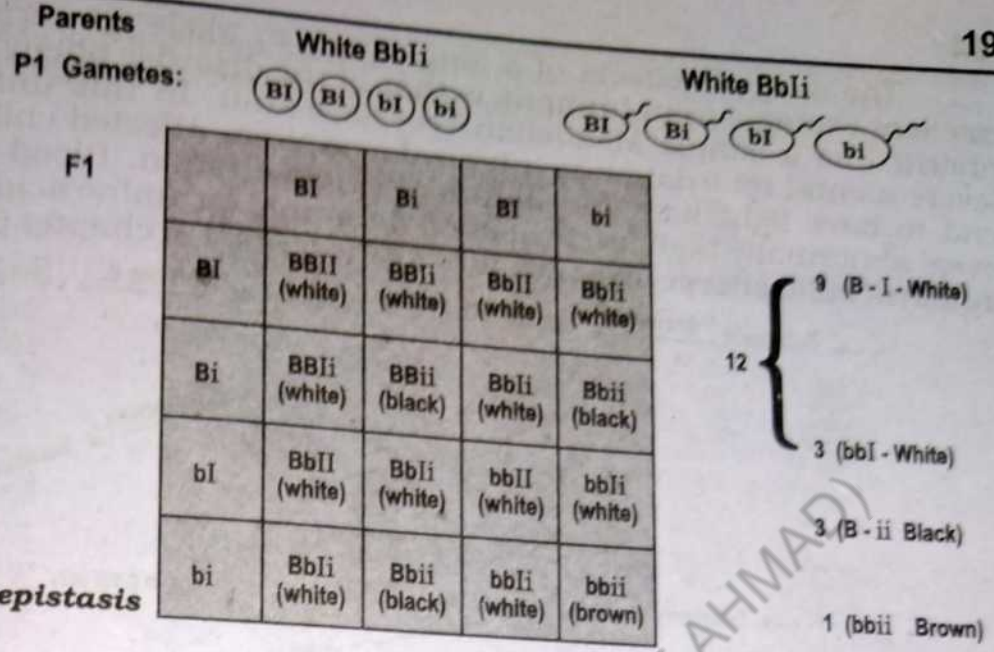


Fig: 8.7 Dominant epistasis

8.4.2 Continuously varying trait (Polygenic inheritance):

The traits that are controlled by two or more than two separate pairs of genes, which manifest themselves in an additive fashion to yield continuously varying traits. This is known as **polygenic inheritance**. The simplest polygenic situation occurs when there are at least two gene pairs that affect the same trait in additive fashion. In a certain type of wheat, with coloured kernels, for example, there are two genes pairs for the kernel colour, each with alleles A and a. To distinguish the two pairs, subscript 1 and 2 are used for each gene allele. Thus the dominant alleles are written as A_1 and A_2 while the recessive as a_1 and a_2. With all the dominant alleles A_1 A_1, A_2 A_2 four doses of pigments are produced, thus the colour of the kernel will be deep dark red. With all the recessive alleles a_1 a_1, a_2 a_2, no pigment is produced and colour remains white. The intermediate number of dominant alleles yields intermediate intensities of red colour.

Skin colour, height and intelligence are polygenic traits in human beings. Number of flowers, fruits and seeds produced by plants and quantity of milk, meat and egg produce by animals are also some of the example of polygenic traits.

8.4.3 Pleiotropy (interrelated pathways in metabolism):

Few synthetic pathways are simple. Most of them are not independent but are linked to others, so that any one product in a sequence may be essential to one additional pathway or more (Fig: 8.8). In the illustration, a lack of C substance leads to defects in two end products A and Z, because both pathways leading to them require C for their completion. Since metabolic pathways are commonly interrelated in this way, it is not surprising to learn that a gene, when studied carefully, is often found to have more than one phenotypic effect. One of these may be more pronounced than the others, but the latter are real and detectable.

In the fruit fly, the recessive allele responsible for white eye colour also influences the colour of the testes and even the shape of the sperm receptacles in the female. In cats, the genetic factor responsible for white fur and blue eyes also results in deafness.

The multiple effects of a single gene or allele are termed pleiotropy. One excellent example from humans is that of the disorder phenylketonuria, which is inherited as a simple Mendelian recessive trait. In this unfortunate condition, Severe mental retardation is a typical symptom. Affected children, however, also tend to have light hair and light skin pigmentation. Blood and urine analyses reveal abnormally high levels of phenylalanine, an amino acid concentrated in the protein of milk, cheese, eggs etc. already described in chapter 6.

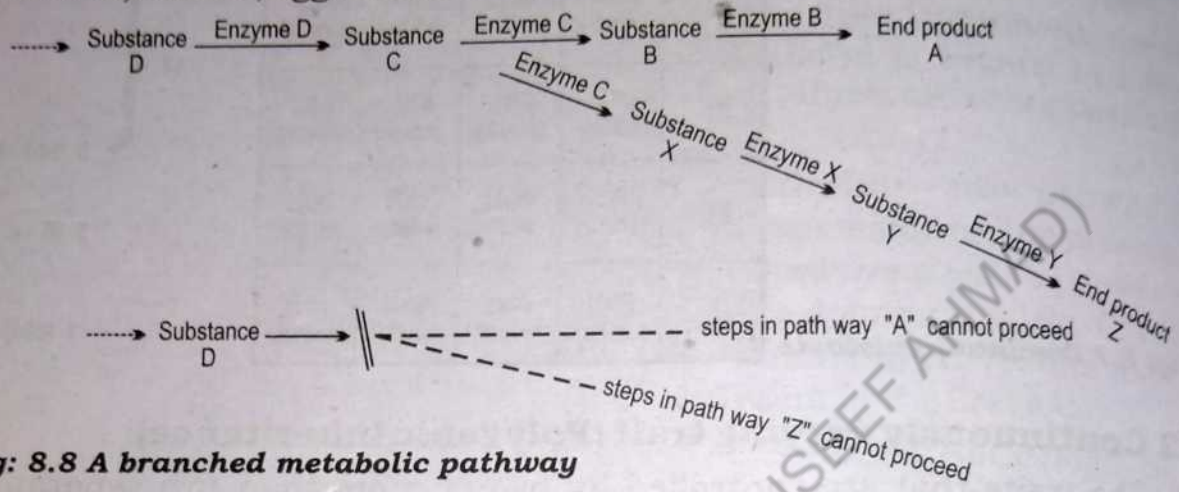


Fig: 8.8 A branched metabolic pathway

8.5 LINKAGE AND CROSSING OVER

According to a conservative estimate, there are thousands of genes in the four pairs of chromosomes of Drosophila. It means that each chromosome contains a large number of genes, similar is the situation in all organisms. The chromosomes behave as single units. All the genes in a given chromosome tend to remain together during inheritance. This tendency of genes in a chromosome to remain together is called **linkage**. However, this linkage is not absolute and the genes do not remain locked up in the same chromosome forever. Otherwise, the inheritance of traits would also have remained constant. During meiosis, the homologous chromosomes come together and form pairs, a process called **synapsis**. Then soon after they sometimes exchange segments mutually, a process called **crossing over**. This exchange occurs randomly along the length of chromosomes. After separation, the chromosomes carry some genes that were earlier located in a different member of their pair of the homologous chromosome (Fig: 8.9).

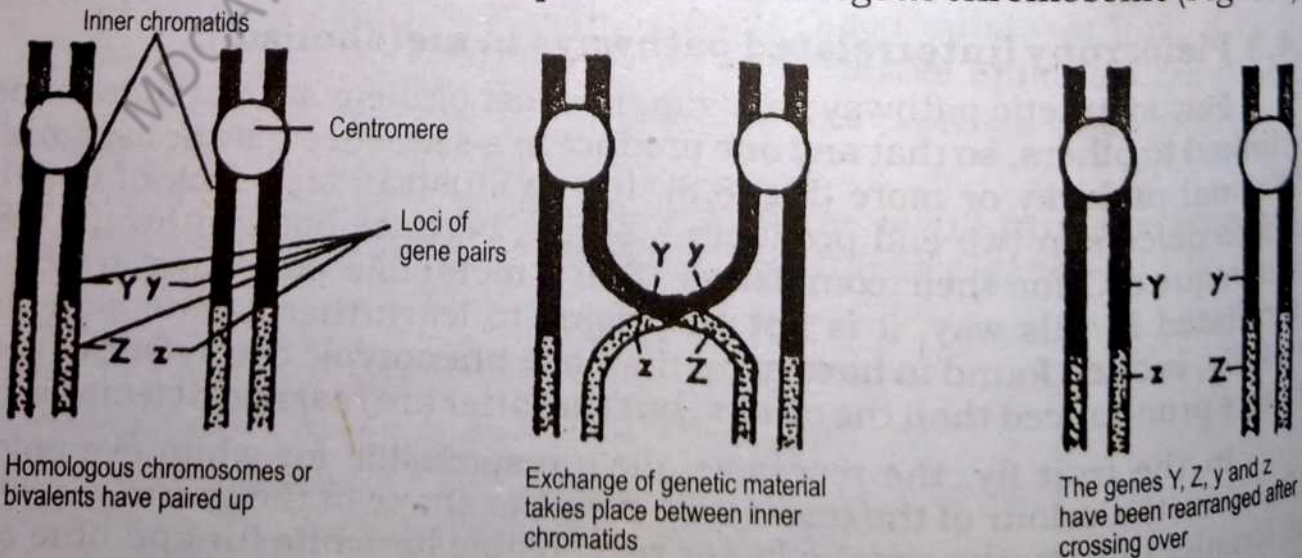


Fig: 8.9 Crossing over

Such exchanges of chromosomal segments or crossing over may occur at more than one point in homologous chromosomes in a single meiotic division (Fig: 8.9).

In *Drosophila* the dominant gene V for normal wings and its recessive allele v for vestigial wings and the dominant gene B for grey body colour and b for black body colour are located in the same pair of chromosomes (Fig: 8.10). As they are linked, they tend to be inherited together i.e. V with B and v with b.

It implies that when a homozygous VVBB fly is crossed with a homozygous vvbb fly, all offspring would be Vv Bb i.e. normal winged, gray body colour flies. When one of these heterozygous flies is crossed with a homozygous recessive vvbb and the genes remain completely linked, and no crossing over takes place, then only two types of individuals would appear equally in the offspring that would resemble the two Parents i.e. gray bodied normal winged (VvBb) and black bodied, vestigial winged (vvbb) (Fig: 8.10).

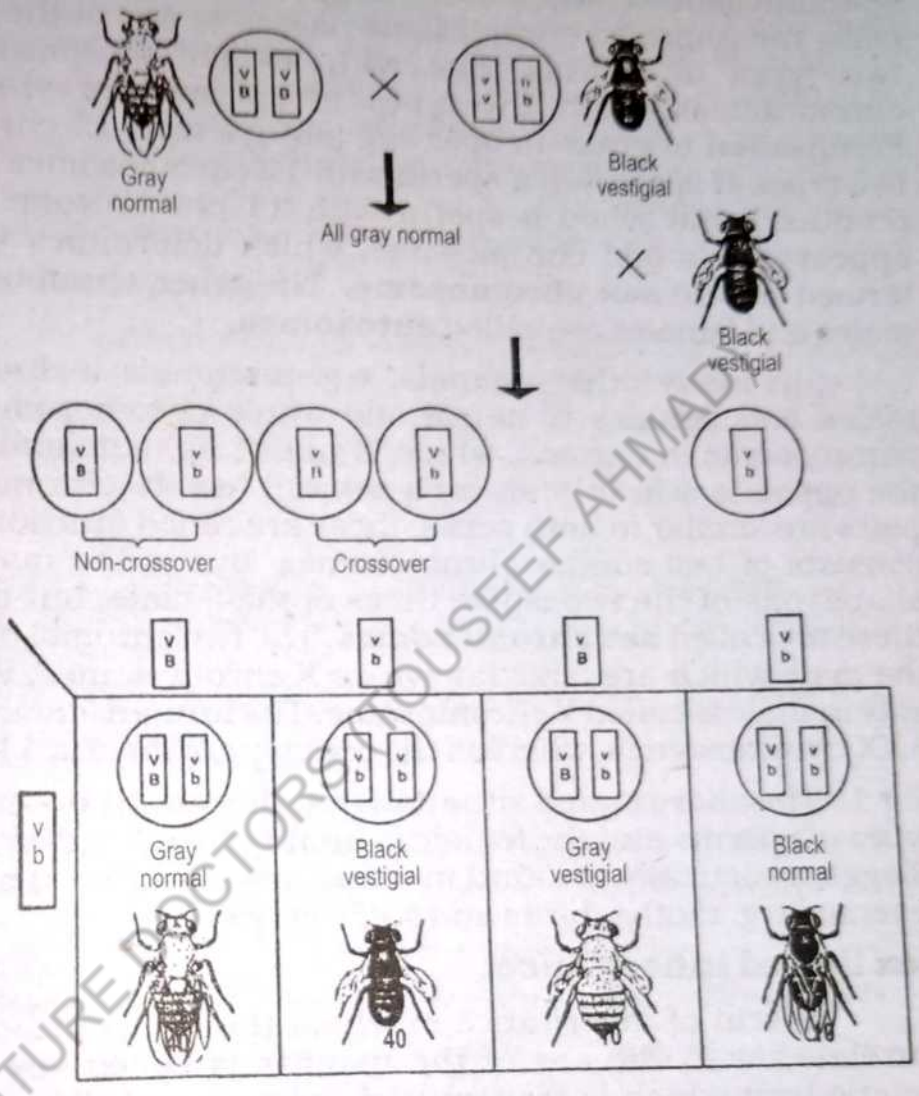


Fig: 8.10
Diagram of a cross involving linkage and crossing over. The genes for vestigial versus normal wings and black versus gray body in fruit flies are linked; they are located in the same chromosome

8.6 SEX DETERMINATION AND SEX LINKAGE

It was found in the early years of this century that whereas in plants and animals most of the chromosomes are pairs of homologous chromosomes, the members of one pair are not homologous, i.e. the two differ from each other morphologically. The exact pattern of differences of chromosomes between males and females of various organisms is different. The simplest situation of chromosomal difference is found in grass-hoppers, in which the males have one chromosome less than the female i.e. the females have 24 and the males have only

23. As the females possess 12 pairs all the eggs possess half of 24 chromosomes. Males, however, have only 23 chromosomes i.e. 11 pairs + one. At the time of spermatogenesis, when every single cell divides finally to give rise two daughter cells, the unpaired chromosome passes to one of the daughter cell, giving rise to two types of sperms, one with 11 chromosomes and the other with 12 chromosomes. Both the types of sperms are produced in equal numbers. Fertilization of grass-hopper egg (always with 12 chromosomes) is possible with two types of sperms. If a sperm with 12 chromosomes fertilizes the egg, a female is produced, but when a sperm with 11 chromosomes fertilizes the egg, a male appears. This odd chromosome, which determines the sex of the individual, is termed as the **sex chromosome**. The other chromosomes which are similar in males and females are called **autosomes**.

In many other animals, e.g. mammals including man, the difference in males and females is not of one whole chromosome, but of the shape of one chromosome in one sex, which is unlike its mate and unlike any chromosome in the opposite sex. In man each sex cell has 46 chromosomes, of which 44 i.e. 22 pairs are similar in both sexes, these are called autosomes. The 23rd pair in female consists of two similar chromosomes, but in the male of the 23rd pair differ in shape, one of the two is like those of the female, but the second is much smaller, these are called **sex chromosomes**. The two chromosomes of the female and one of the male which are alike known as X chromosomes, while the unlike smaller one only in male is called Y chromosome. The human female possesses a genotype of 44 + XX chromosomes, whereas the genotype of male is 44 + XY chromosomes.

The above stated situation that the male is **heterogametic** i.e. produces two types of sperms and the female is **homogametic** i.e. produces similar and one type of eggs, genetically is found in many animals. But in some animals the position is reversed e.g. moths, birds and some fishes.

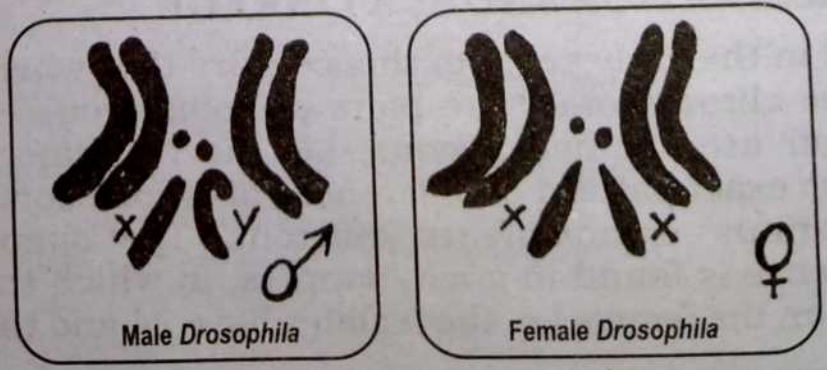
Sex linked inheritance:

A form of inheritance in which the transmission of the genetic material is correlated with the sex of the parents is called sex linked inheritance, or any genetic trait which is transmitted through sex chromosomes is called sex linked inheritance.

Sex determination in *Drosophila*:

Drosophila melanogaster (Black-bellied dew lover) is a common fruit fly which can be seen hovering around over ripe fruits.

T.H. Morgan, a Nobel prize winner (1933) first selected this fly as his experimental animal. He noted that the male and female *Drosophila* have differences in the chromosomes. The karyotype is shown in figure 8.11.



Male *Drosophila* Female *Drosophila*

Fig: 8.11

This shows that there are three pairs of chromosomes which are same in male, as well as female fly. These are called as autosomes, but the difference lies in 4th pair. The female has both the chromosomes of the 4th pair similar and rod-shaped. On the other hand male has both the chromosomes different from one another. One chromosome is rod shaped and other is hook shaped. This fourth pair of chromosomes has been designated as sex-chromosomes because this pair is going to decide the sex in *Drosophila*. Moreover the rod shaped sex chromosomes, two of the female and one of the male, which are alike are called X chromosomes. The unlike sex chromosome is called Y. *Drosophila*. Individual getting XX will be a female and that receiving XY will be a male.

Sex linked inheritance in *Drosophila*:

T.H. Morgan (1910), performed various breeding experiments with wild type red-eyed drosophila flies. He noticed a white eyed **mutant**. This was male and turned out to be a true breeding strain of white-eyed flies. He crossed this white-eyed male with true red-eyed female. The F_1 and F_2 population followed the simple Mendelian ratio. But when white-eyed female was crossed with red-eyed male, the results were not similar.

To examine the details of various crosses made by **T.H. Morgan**, we are giving their representation in figures. We have represented the R for red-eyed and r for recessive white-eyed flies.

CROSS I: When red-eyed female ($X^R X^R$) is crossed with white eyed male ($X^r Y$) the F_1 generation shows all red flies, female as well as male.

The F_2 generation shows red-eyed and white-eyed flies in ratio of 3:1 (all females are red, but ½ male red and ½ male white eyed). Again female flies were of two types. One producing only red-type offspring and another producing half red-eyed and otherhalf white-eyed offsprings.

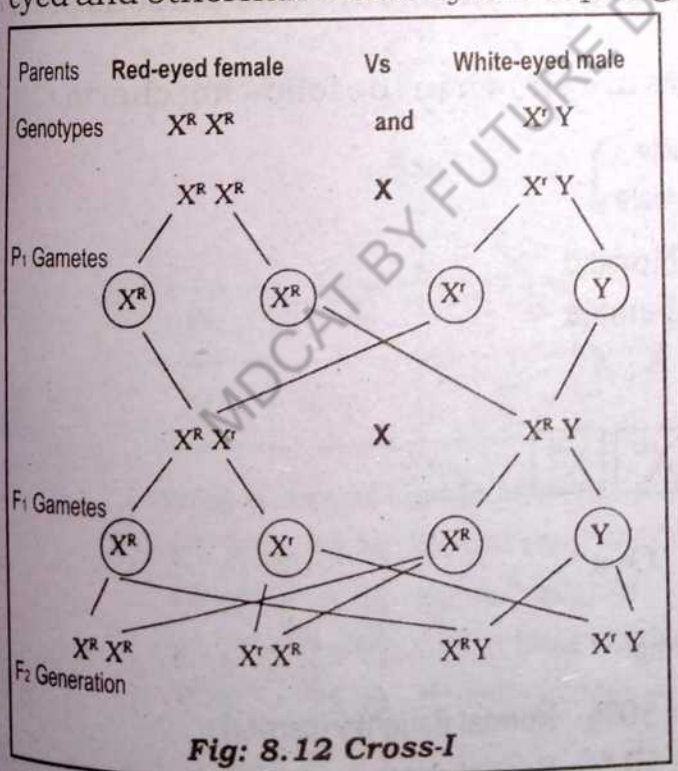


Fig: 8.12 Cross-I

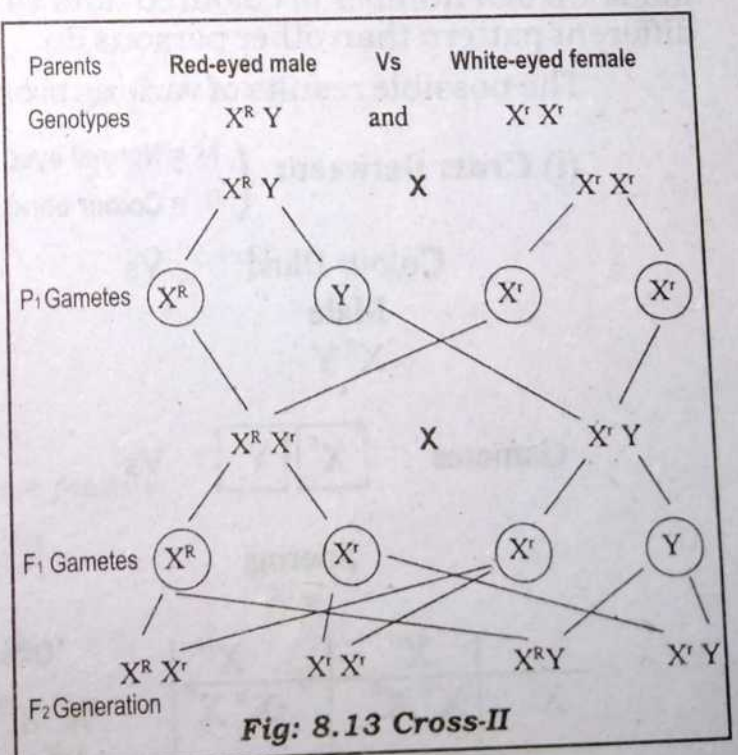


Fig: 8.13 Cross-II

CROSS II: When red-eyed male ($X^R Y$) is crossed with white-eyed female ($X^r X^r$) results are different from cross-I. In F_1 both types of flies were produced that is red-

eyed and white eyed. Moreover all the red-eyed are females and all the white eyed males. In F_2 generation again red and white-eyed appeared in equal ratio and very interesting case is that half of the male were red-eyed and half white-eyed. Similar is the case with female flies.

T.H. Morgan on the basis of results obtained from his experiments concluded that eye colour in Drosophila is present in X chromosome. The Y chromosome carries no allele for eye colour.

Sex-linked inheritance in man:

In human beings, male has XY sex chromosomes while female has XX chromosomes. There are about 200 genes present on human X chromosome. There are two most popular sex linked traits found in human beings. These deductions are purely based on interpretation of family histories, as it is not possible to conduct practical on human beings. The two sex linked inheritance are described as follows.

> Pedigree analysis is the acquiring of information about the phenotypes of family members to infer the genetic nature of a trait from the pattern of its inheritance.

a) Colour-blindness:

It is a sex-linked inheritance found in human beings. Persons suffering from colour blindness have difficulty in distinguishing red from green. It is a rather common trait and more common in males. It is because Y chromosome is inert for this trait. Only one gene of this trait will render a colour blind man. While on the other hand a woman must have two genes for this trait to become colour blind.

This trait of colour blindness can easily be detected by using special charts made up of a number of coloured dots so arranged that colour blind persons see a different pattern than other persons do.

The possible results of various crosses are shown in the following charts.

(i) Cross Between: (N = Normal eyed male, n = Colour blind female)

Colour Blind Male X^nY Vs Normal Female X^NX^N

Gametes X^n Y Vs X^N X^N

Sperms Ova

	X^N	X^N
X^n	X^NX^n	X^NX^n
Y	X^NY	X^Ny

Offspring

X^nX^N = 50% Normal daughter(carrier)

X^Ny = 50 % Normal sons

When a colour blind male marries a normal female, all children will be normal but daughters will be colour blind carriers.

(ii) Cross Between:

Normal Male $X^N Y$ Vs Colour Blind Female $X^n X^n$

Gametes X^N Y Vs X^n X^n

Sperms Ova

	X^n	X^n
X^N	$X^N X^n$	$X^N X^n$
Y	$X^n Y$	$X^n y$

Children
$X^N X^n$ = 50% Normal daughter(carrier)
$X^n y$ = 50 % Normal sons

When a colour blind male marries a normal female, all the sons will be colour blind, while all daughters will be normal but carriers.

(iii) Cross Between:

Normal Male $X^N Y$ Vs Carrier Female $X^n X^N$

Gametes X^N Y Vs X^n X^N

Sperms Ova

	X^n	X^N
X^N	$X^N X^n$	$X^N X^N$
Y	$X^n Y$	$X^N y$

When a normal male marries carrier female:

$X^N X^n$ = 25 % Normal daughter(carrier)
$X^N X^N$ = 25 % Normal daughter
$X^n Y$ = 25 % Colour blind children
$X^N Y$ = 25 % Normal children

(iv) Cross Between:

Colour Blind Male X^nY Vs Normal (Carrier) Female X^NX^n

Gametes $(X^n)(Y)$ Vs $(X^N)(X^n)$

Sperms Ova

	X^N	X^n
X^n	X^NX	X^nX^n
Y	X^NY	X^ny

Offspring
X^NX = Normal female(carrier) 25%
X^NY = Normal male 25%
X^nY = Colour blind male 25%
X^nX^n = Colour blind female 25%

When a colour blind male marries a carrier female, 50% daughters carrier and colour blind and 50% sons colourblind and normal.

B) Haemophilia:

It is a sex-linked inheritance found in human-beings. It is a defect in which the blood fails to clot after an external or internal injury, or it clots very slowly. Persons with extreme cases can bleed to death from even a small cut. Thus it is a very serious or even a lethal defect.

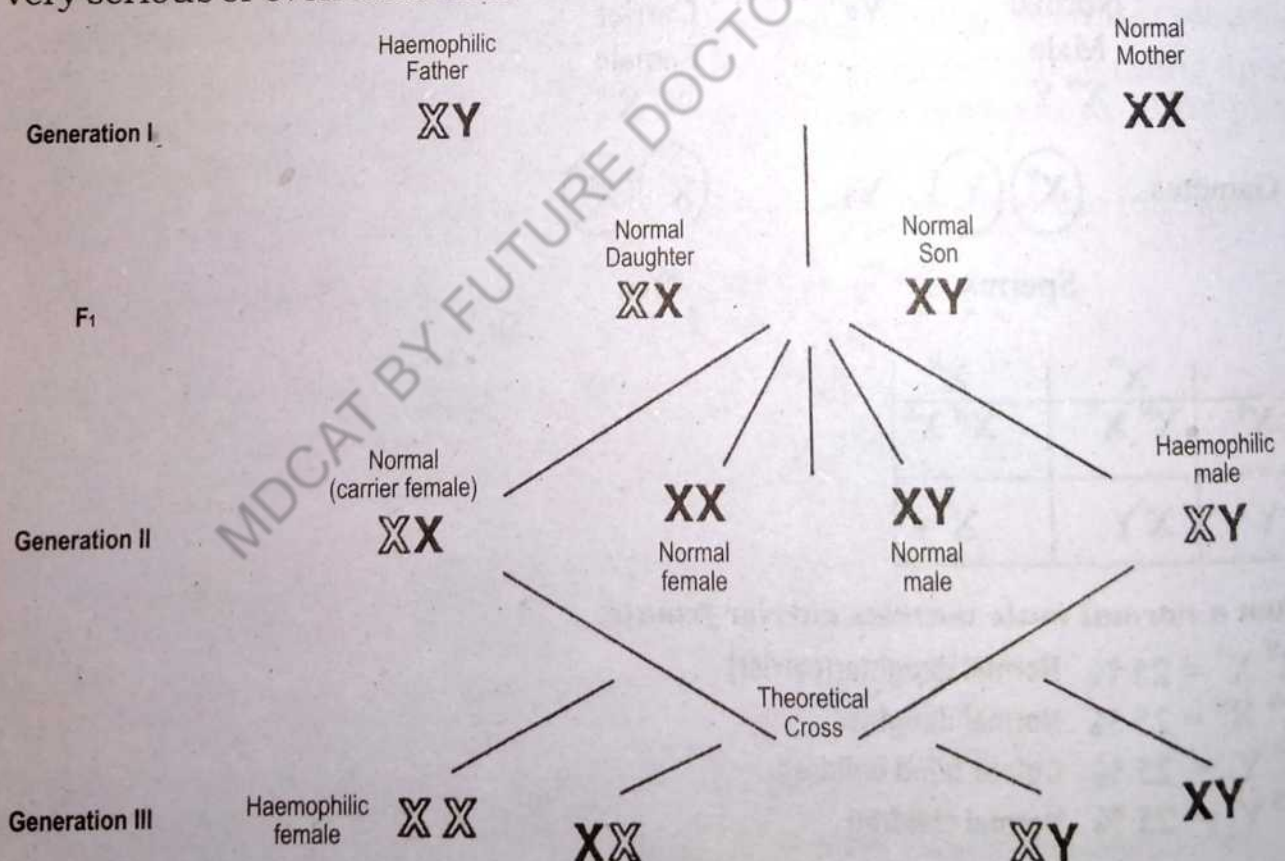


Fig: 8.14 Inheritance of sex linked recessive gene for haemophilia on X Chormosomes (X = chromosome with normal gene and X = chromosome with gene for haemophilia)

Haemophilia is comparatively very rare in women. The reason is the same. The Y chromosome is inert for this trait. A man needs only one gene controlling this trait while a women needs two genes. This occurs very rarely because few haemophilic male survive and reproduce (Fig 8.14).

8.7 DIABETES MELLITUS

Diabetes mellitus, perhaps the best known endocrine disorder, is caused by a deficiency of insulin or a loss of response to insulin in target tissues. The result is high blood glucose, so high, that the diabetic's kidneys excrete glucose, which explains why the presence of sugar in urine is one test for diabetes. As more glucose concentrates in the urine, more water is excreted with it, resulting in excessive volumes of urine and persistent thirst. Because glucose is unavailable to most body cells as a major fuel source for diabetics, fat must serve as the main substrate for cellular respiration. In severe cases of diabetes, acidic metabolites formed during fat breakdown accumulate in the blood, threatening life by lowering blood pH.

There are actually two major forms of diabetes with very different causes:

Type I Diabetes Mellitus (insulin-dependent diabetes) is an autoimmune disorder, in which the immune system mounts an attack on the cells of the pancreas. This disorder usually occurs rather suddenly during childhood, destroying the person's ability to produce insulin. Treatment consists of insulin injections, which are usually taken several times daily. Until recently, insulin for injections was extracted from animal pancreases, but genetic engineering has provided a relatively inexpensive source of human insulin by inserting the gene for the hormone into bacteria.

Type II Diabetes Mellitus (non-insulin-dependent diabetes) is characterized either by a deficiency of insulin or more commonly, by reduced responsiveness in target cells due to some change in insulin receptors.

Type II diabetes usually occurs after about age 40, becoming more likely with increasing age. More than 90% of diabetics are type II, and many can manage their blood glucose solely by exercise and dietary control. Heredity is a major factor in type II diabetes.

KEY POINTS

- Genes are the basic units of inheritance, consisting of a sequence of DNA that occupies a specific position on a chromosome.
- The total aggregate of genes in a population at any one time is called the population's gene pool.
- The cross between two parents differing in one trait is called monohybrid-cross and the ratio obtained in F2 generation is called monohybrid-ratio.

- The result obtained from mono hybrid cross is spoken as single trait inheritance.
- Cross fertilization of a phenotypically dominant individual with a homozygous recessive individual is called a Test-Cross. It helps in determining the Homozygosity or Heterozygosity of the dominant parent.
- Codominance may be described as phenomenon of inheritance in which both alleles of a contrasting character are dominant and express themselves in heterozygous individual neither masking the effect of one another.
- A gene for a trait having three or more allelic forms are called multiple alleles.
- The traits that are controlled by two or more than two separate pairs of genes which manifest themselves in an additive fashion result in yielding continuously varying traits. This is known as polygenic inheritance.
- The multiple effects of a single gene or allele are termed pleiotropy.
- The tendency of genes in a chromosome to remain together is called linkage.
- Any genetic trait which is transmitted through sex chromosomes is called as sex linked inheritance.

EXERCISE

1. Encircle the most correct choice:

i) Mendel perform his famous experiments of heredity on
a) Maize b)Mirabilis plant
c) Garden pea d) Bean plants.

ii) Mendel in his experiments considered how many characters:
a) Fine b) Three c) Six d) Seven

iii) In a cross, appearance of intermediate character is known as
a) Codominance b) Incomplete dominance
c) Epistasis d) non of them

iv) If in a cross both contrasting characters equally appear then it is called
a) Codominance b) Incomplete dominance
c) Interaction of genes d) Multiple alleles.

v) Blood group which is also known as universal donor
a) Blood group A positive b) Blood group O negative
c) Blood group AB positive d) Non of them.

vi) Each human being possesses pairs of chromosomes
a) 21pairs b) 22pairs c) 23pairs d) 24pairs

vii) Which chacteristic is not associated with diabetes mellitus
a) Endocrine disorder b) Insulin defficiency
c) Low blood gulcuse d) Persistent thirst

viii) Point out the mis-match
a) T.H. Morgan → Drosophila
b) G. Mendel → Garden pea
c) Epistasis → Bateson
d) Dominant epistasis → 9:3:4

ix) The total aggregated of genes in a population at any one time is called
A) Gene-pool b) Linkage
c) Crossing-over d) Genome

x) The muttiple effects of a single gene or allele are termed as
a) Polygenic inheritance b) Pleiotropy
c) Continuously varying trait d) Multiple inheritance

2. Write detailed answers of the following questions:

i) Define and explain the law of segregation taking an example from plant or animal.

ii) Explain the phenomenon of incomplete dominance and Co-dominance with the help of examples.

iii) Explain multiple-allele by taking the example of human's blood group. Also write about rhesus-factor and erythroblastosis.

iv) Explain the phenomenon of continuously varying trait and pleiotropy with examples.

v) What do you mean by sex-determination and sex linkage. Discuss sex-linked inheritance in humans.

3. Write short answers of the following questions :

i) What is a gene? Define allele.

ii) Define gene-pool.

iii) State Mendel's law of segregation.

iv) What is law of independent assortment.

v) What is a test-cross?

vi) What is incomplete dominance?

vii) How would you explain the inheritance of the skin colour in human beings or the colour of kernel in corn?

viii) Write in detail the importance of inheritance of R^h factor in human beings, particularly if an R^h- woman marries an R^h+ man.

4. Distinguish between the following in tabulated form:

i) Single and double trait inheritance.

ii) Monogenic and polygenic inheritance.

iii) Linkage and crossing over.

iv) Sex and autosomal inhritance.

5. Define the following terms:

i) Monohybird retio ii) Epistasis

iii) Autosomes iv) Heamophilia

6. Solve the following problems by showing genetic crosses:

i) In garden pea, tall stem(T) is dominant over dwarf stem(t); round seed(R) is dominant over wrinkled seed(r):

Yellow cotyledons(Y) is dominant over green cotyledons(y);

inflated pods(S) dominant over constricted pods(s);

green pods(G) dominant over yellow pods(g) and axial flowers(A) is ominant over terminal flower(a). Find out the phenotypic ratio of each cross:

a) Tt Rr X Tt rr b) TTrr XTt Rr c) tt RrX Ttrr

d) Tt rr X Tt Rr e) Yy Ss X Yy ss f) Yyss X YySs

g) yySs X Yyss h) Yyss X YySs i) GgRr X Ggrr

j) GGrr X Ggrr k) AaTt X aa tt l) GgYy X Ggyy

ii) Find out the possible blood groups and genotypes of the children of following parents:

a) Mr. x = O group b) Mr. y = A c) Mr. z = A

Mrs. x = B group Mrs. y = AB Mrs. z = A

iii) If the new born babies get mixed up in a hospital, how could you determine their parentage from the information given below. Also give the possible genotypes of the six persons.

Baby I	Type	O
Baby II	Type	B
Mrs. Zafar	Type	A
Mr. Zafar	Type	AB
Mrs. Saleem	Type	A
Mr. Saleem	Type	A

CHAPTER 9

BIOTECHNOLOGY

Genetic engineering is the manipulation of genetic material for practical purpose. This DNA recombination technology has launched an industrial revolution in biotechnology. In broad terms, biotechnology is the manipulation of living organisms or their components to perform practical task or provide useful products. In past it was used to make wine and cheese by microorganisms, the selective breeding of live stock and field crops, production of antibiotics from microorganism and synthesis of antibodies. Recently reproductive cloning intended to produce genetically identical animal like revolutionary sheep, the Dolly.

A century ago, **Gregor Johann Mendel** formulated set rules to explain the phenomenon of inheritance of biological characteristics. The basic theme is that each heritable property of an organism is controlled by a factor called a gene, a physical entity present somewhere in the cell, which is made up of DNA. The discovery of the role of DNA was a tremendous stimulus to genetic research. From 1952 - 1966 structure of DNA was studied, the genetic code understood and the processes of transcription and translation were described.

In the year 1971-73, genetic research was activated and a revolution in modern biology occurred. A whole new methodology was developed. These methods referred to as **recombinant DNA technology** or **genetic engineering** and having at their core the process of gene cloning, sparked the third great age of genetics. We are still in the midst of the boom caused by this revolution and there is no end to the excitement insight.

Now, the recombinant DNA technology leads us into the major growing industry of our generation and this century - biotechnology. Biotechnology can be defined as the use of living organisms for the welfare of mankind. In broad terms, biotechnology is the manipulation of living organisms or their components to perform practical task or provide useful products. The biotechnology industry dates back to the dawn of civilization, when fermentation process made use of living yeast cells for rising bread and fermenting sugar for brewing were introduced.

The building of biotechnology is standing on the pillars of recombinant DNA technology. Therefore, in this chapter we will study main techniques and applications of genetic engineering. We will also discuss DNA technology as revolutionary technique, which brings about a revolution in biological research, medicine, forensic science and agriculture.

9.1 GENETIC ENGINEERING

Genetic engineering is the manipulation of genetic material of any organism. Genetic engineering usually utilizes bacterial cells and their plasmids, which are small circular DNA molecule. They can replicate freely within bacterial cells. Genetic engineering can produce cells that contain a foreign gene. These cells are capable of producing a new and different protein. As a result of growth of these cells so many identical copies of plasmid with a foreign gene are produced.

9.1.1 Recombinant DNA technology:

The basic steps in recombinant DNA technology are:

1. Preparation of recombinant DNA (rDNA) molecule.
2. Insertion of rDNA into host cell.
3. Multiplication and production of numerous copies of host with rDNA in it.
4. Selection of bacteria with required gene.

1. Preparation of recombinant DNA (rDNA) molecule:

Recombinant DNA (rDNA) molecule is a DNA molecule, which contains DNA

from two sources. Preparation of this type of DNA requires some basic tools, these tools are vector (Plasmid or bacteriophage), restriction enzyme and DNA ligase enzyme.

Vector: It is a DNA molecule into which a gene is inserted to construct a recombinant DNA molecule. It is capable of replication in host organism. It acts as a vehicle to transport rDNA into host cell, which is usually a bacterium. Two most popular types of vectors used in this technology are bacterial plasmids and bacteriophage (virus).

Plasmids are small, extra chromosomal circular DNA molecules found in some bacteria. It can replicate independent of the host cell chromosome. Plasmids always carry one or more genes, which are responsible for useful characteristics displayed by host bacterium such as resistance to antibiotics, fertility, killing of other bacteria (colicins) etc.

Generally plasmids are found in bacteria but rarely they are also found in some eukaryotes i.e. in some strains of yeast.

Plasmids are used to prepare recombinant DNA molecules by removing it from their source and inserting a foreign (required) gene into them. Host cells take up this rDNA as vector and there after both bacteria and plasmid reproduce.

Restriction enzyme:

Another tool for recombinant DNA technology is a group of enzymes, which are required to cut a source DNA molecule into small pieces and to cut plasmid to make a gap where foreign DNA fits into it.

These enzymes are naturally found in bacteria to protect them against bacteriophage by cutting viral DNA. These enzymes can be considered as molecular scissors due to their restricting property of viral growth. They were discovered in 1960s. Different types of restriction enzymes have been isolated and purified. Each one cuts DNA at a specific palindromic site, producing **sticky ends**. The sticky ends of restriction fragments are used in the laboratory to join foreign DNA pieces.

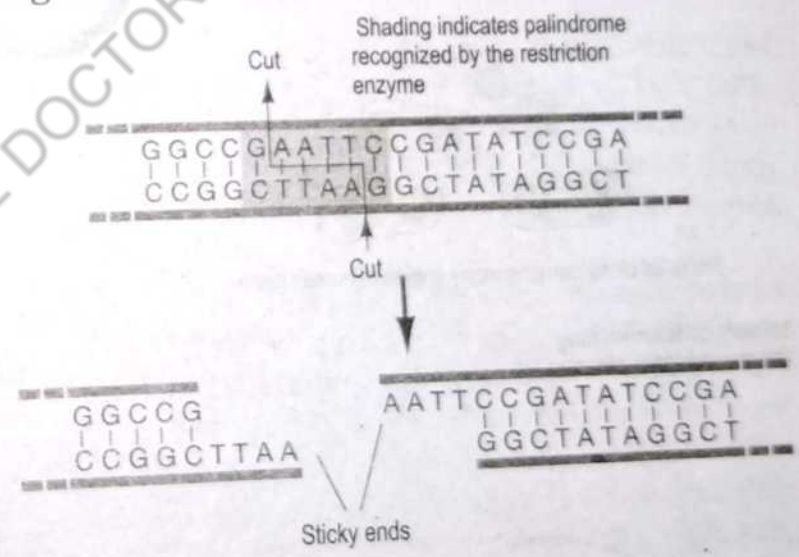


Fig: 9.1
Restriction enzymes cut apart double-stranded DNA at specific nucleotide sequences

DNA Ligase Enzyme:

DNA ligase is a key enzyme that seals the restriction fragment with sticky ends of vector.

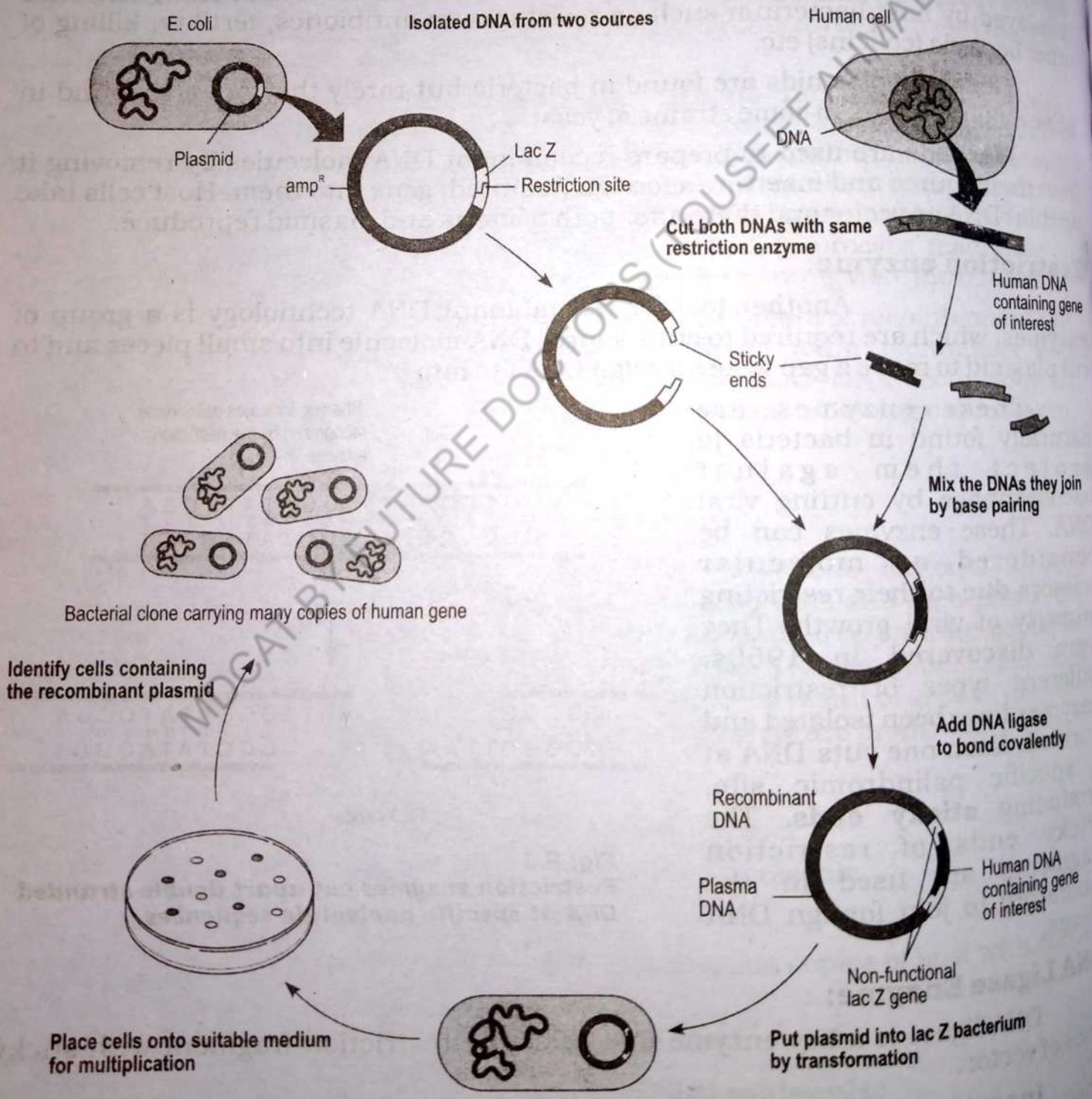
2. Insertion of rDNA into host cell:

Usually the bacterial cells are used as host in recombinant DNA technology because it is easier to isolate and reinsert rDNA in bacterial cells. Bacterial cells

take up rDNA when they are treated with calcium chloride to make them more permeable. Some of the host (bacteria) will take the desired plasmids DNA from solution, as well as bacteria.

3. Multiplication of host with rDNA:

When the host cell divides and redivides, copies of the recombinant DNA molecules are passed to the progeny and further replication of vector takes place. After a large number of cell-divisions, a colony or clone of identical host cells is produced. Each cell in the clone contains one or more copies of the rDNA molecules. The gene carried by the recombinant molecule is now said **cloned**.



4. Selection of bacteria with foreign gene:

Bacteria containing required gene in plasmid (rDNA) can be identified from other bacteria having no rDNA by growing them in a medium containing ampicillin. Thus only those bacteria containing amp^R gene will be able to survive and establish colony, while the rest will die. The culture medium also containing x-gal (a modified sugar), which is cleaved by lac-z gene of vector. In a colony, if plasmid does not carry desired gene, the x-gal will be hydrolyzed by β-galactosidase yielding a blue colour. However, colonies carrying plasmid with foreign gene would be unable to produce β-galactosidase, so they appear white in colour. Thus only those colonies of bacteria will be selected that form white colour on medium containing ampicillin and x-gal.

Application of genetically engineered bacteria:

Genetically engineered bacteria can be used in the environment, for serving in the field of agriculture, etc. These bacteria can also be used to promote health of plants to make them resistant towards insects, as bioremediation (pollution cleaner), to synthesize organic chemicals, to detect metals, to enhance genetic research to produce pharmaceutical products.

In agriculture these bacteria can be used to promote the health of plant in different ways. Some bacteria, which live on plant transform from frost plus to frost minus bacteria. Earlier they use to promote frost damage of plants, now they prevent it. Some bacteria, which normally live in the roots of corn are transformed for producing insect-killing toxins.

There are some bacteria, which have an ability to degrade some chemical material e.g. oil eating bacteria, which were used to clean up the oil spils at beaches. Now there are genetically engineered bacteria that can do this job much efficiently.

Number of chemicals like insulin, which was previously extracted from cattle and pigs can be synthesized by genetically engineered bacteria, these chemical are not synthesized naturally by bacteria.

Production of proteins on large and commercial scale made possible due to genetically engineered bacteria, which was difficult to obtain in past. For instance, human growth hormones were previously extracted from pituitary glands of cadavers (dead organism) and it took 50 glands to obtain one dose. Now it is synthesized by genetically engineered bacteria.

Hormones are also prepared by these cloned bacteria e.g. bovine growth hormone (bGH) if given to cows they produce 25% more milk. Some growth hormones prepared by transformed bacteria can be given to farm animals to produce a leaner meat which is more desirable for humans.

Some genetically engineered bacteria are used to produce phenylalanine, an organic compound to make a sweetener called **nutra sweet**.

Genetic engineering enhances the ability of those bacteria used by miners to extract copper, uranium, and gold from low-grade-sources.

9.1.2 Transgenic plants:

Free living organisms in the environment that have a foreign gene inserted into them are said to be transgenic organisms or genetically engineered organisms.

Plants in particular are easy to genetic manipulation because they can grow by tissue culture, where an entire plant can be grown from a single cell.

Some techniques have been developed to produce transgenic plants. The rDNA can be introduced into embryo or must be in cell-wall-removed cell called protoplast. The only plasmid for transgenic plants cell is Ti-Plasmid, transferred by its host *Agrobacterium* to many but not all plants.

The main aims of developing transgenic plants are:

a) To cultivate more nutritious plant, seeds of these plants contain all the amino acids required by human. Protein enhanced beans, soybeans, corn and wheat are now developed.

b) Plants require less fertilizer and are able to make use of nitrogen from atmosphere.

c) Plants grow under harsh and unfovourable conditions.

A number of transgenic plants have been developed, which resist either insects, viruses, or herbicides. Crops of soybean, cotton, alfalfa and rice are genetically engineered. The first transgenic fruit approved tomatoes retarded spoilage.

A number of agriculture companies are in the process of developing transgenic wheat and rice to meet the global demand of food. Another area where molecular scientists are working is to increase to CO_2 fixation property by enhancing the efficiency of RuBP (Ribulose biphosphate).

Plants are being engineered to produce fructan instead of dextrose, human hormones, clotting factors and antibodies in their seeds. One type of antibody made by corn can deliver radio-isotopes to tumor cells.

9.1.3 Transgenic animals:

Genetic engineering of animals has begun. Animal cells usually do not take plasmids but it is possible to micro-inject foreign genes into eggs before they are fertilized like micro-injection of bovine growth hormone into the eggs of various animals. It had been done on the hope that the gene will establish itself and transmitted to all the cells of developing organism and even be passed along to the next generation of offspring. This procedure has been used in fishes, chicken, cows, pigs, rabbits and sheeps to produce bigger and heavier varieties. Transgenic trout are also farmed.

Transgenic farm animals are being developed to produce biotechnology products. A transgenic calf has been produced that carries a gene for the production of human lactoferin in cow milk (Human lactoferin is a protein that is involved in iron transport and has antibacterial activity).

Isolation of eukaryotic gene for transgenesis:

Eukaryotic gene or DNA can not be cloned directly from its genome because it often contains long non-coding region (i.e. intron) and bacterial cells are unable to express these genes. To avoid this problem an artificial gene can be made which lack introns. In first step transcription of an intron-containing gene in the cell

nucleus yields a pre-RNA molecule. In the next step intron RNA are removed and spliced the exon RNA together to produce mRNA. This mRNA molecule is isolated from cell and used as template to synthesize a complementary DNA (cDNA) strand. This synthesis of cDNA on mRNA template is the **reverse transcription**, being catalysed by an enzyme **reverse transcriptase**, obtained from retroviruses. Now a single strand of DNA is synthesized. The RNA is degraded. The second DNA strand is made using DNA polymerase using the first strand as template. The result is a double-stranded molecule of DNA carrying the coding sequence of the gene but no intron. This is called **complementary DNA** or **cDNA**.

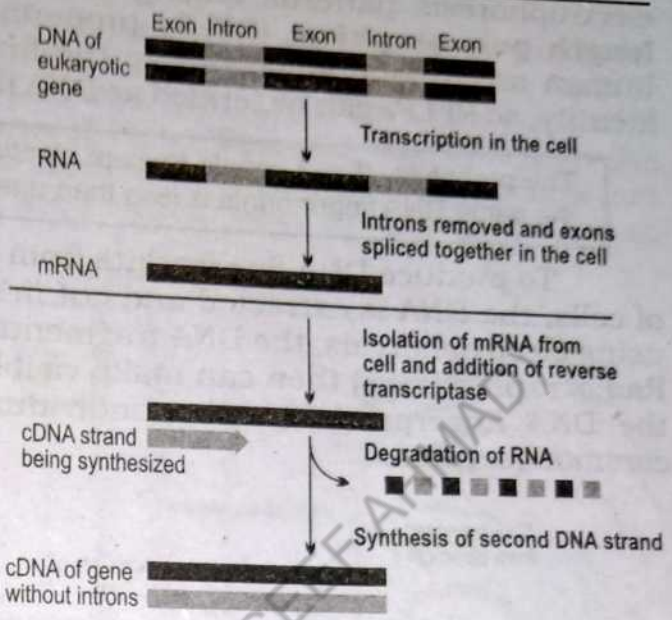


Fig: 9.3 Making complementary DNA (cDNA) for a eukaryotic gene

9.1.4 Gene sequencing:

Gene sequencing is a method of determining nucleotide sequence of a gene (DNA molecules) developed in late 1970s by Frederick Sanger. This gene sequence can provide a great deal of information. It is often the fastest way to determine the amino acid sequences of its poly-peptide. Moreover, it provides the location of restriction site within a gene which can be manipulated further later on.

The main phases of gene sequencing are firstly, to cut genes into specific small pieces, then each fragment is individually sequenced. Most sequences that are determined are being collected in computer data bank that are valuable for biotechnology. With the help of computers long sequences can be scanned for shorter segments known to be control sequences, such as promoter or enhances. It is also possible to scan a DNA sample for similarities to known sequences in other genes or other organisms. This comparison of sequences provide new tool for classifying organisms and determining evolutionary relationships.

> Gel electrophoresis can separate DNA fragments differing even in as one nucleotide than each other.

DNA fingerprinting:

It has been observed that about 30 percent of human DNA does not code for proteins and repeated frequently in genome of that individual. Although, these repetitive units vary in length from person to person, each of such repetitive DNA sequence are of 20-40 bases long. These highly variable and virtually unique lengths of non-functional DNA are passed on to the offspring alongwith the compliments of genes in a Mendelian fashion. The differences in DNA

electrophoresis patterns among individuals are called **restriction fragments length polymorphism** (RFLPs pronounced as Riff-Lips). Since RFLPs of each human are unique analogous to the fingerprints, which are used as marks of identity, so RFLPs can be termed as DNA fingerprints.

> The probability that 2 people (except identical twins) selected at random would have the same DNA finger prints is less than one in a billion.

To produce DNA fingerprints from a sample of blood cells or any other type of cells, the DNA is extracted and cut in fragments by restriction enzymes. Then using electrophoresis, the DNA fragments are separated on the basis of their size. Radiograph (x-rays) then can make visible the DNA fragments. In the same way, the DNA fingerprints of other individuals can be obtained and analyzed for common features.

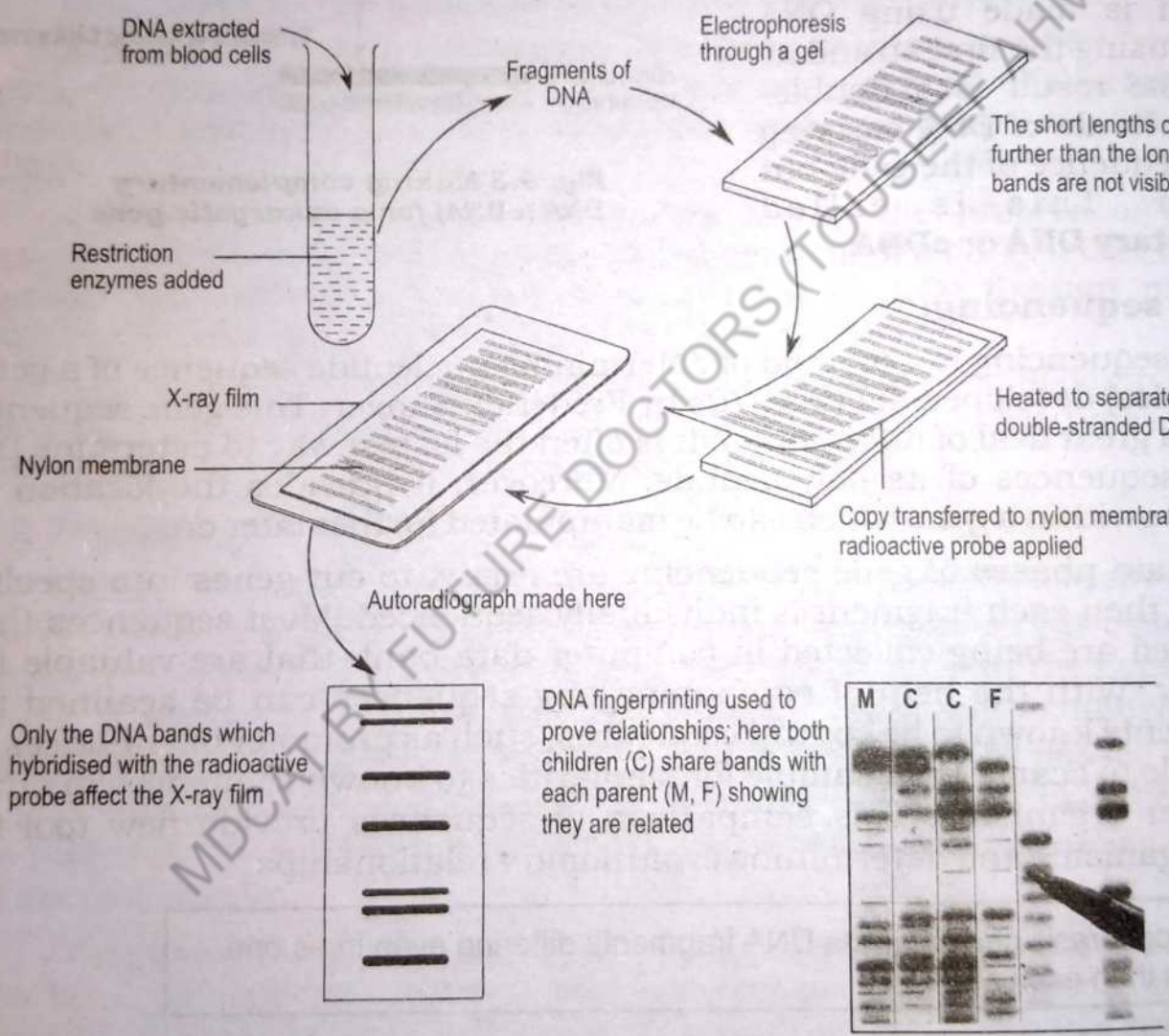


Fig: 9.4 Genetic fingerprints

DNA fingerprinting is used to settle disputes over parentage and other relationships. It is also used to identify criminals from blood, semen, saliva, hair follicles etc. left at the scene of a crime. It has also spectacular potential for medicine, for instance in the prenatal diagnosis of inherited disorders. In figure 9.4 analyze and match the DNA fingerprints of children (C) with their mother (M) and father (F).

Genomic-Library:

It consists of copy of genetic information of a species in a preferred environment. This library provides easy access to a preferred gene for its further copying or manipulation. In order to establish a genomic library of a particular species, its DNA is fragmented by means of restriction enzymes and then the fragments are inserted into the plasmids and bacteriophages, which are introduced into bacteria. Such bacteria are cultured at controlled conditions so that they can be used later on.

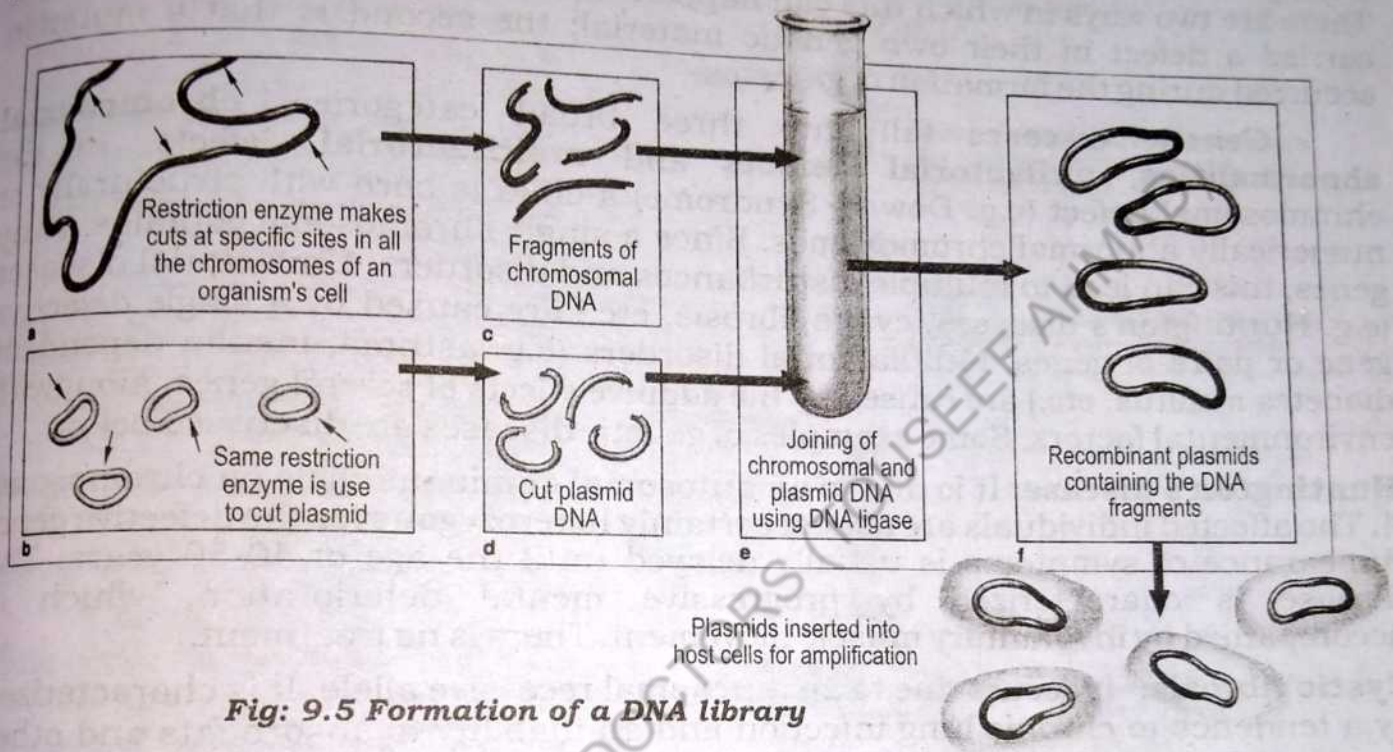


Fig: 9.5 Formation of a DNA library

9.1.5 Human Genome project (HGP):

It refers to an international 13 years effort formally began in 1990 to discover all the estimated 30,000 to 35,000 human genes located on 23 pairs of chromosomes and make them accessible for further biological studies. Another project goal was to determine the complete sequence of 3 billion DNA subunits. As part of the HGP, parallel studies have been carried out on selected model organisms such as bacterium E. coli and the mouse to help develop the technology and interpret human gene function.

In April 2003, DNA sequence of 99.99% of human genes with 99% accuracy was accomplished. About 99.9% of nucleotide sequence is the same in all human. However 0.1% (about 3,200,000 base pairs) constitute mutations and other sequence variations sprinkled throughout the genome. They account for all genetic differences among the human population.

The study of human genome has enormous potential benefits. For instance, it will reveal the methodology for early diagnosis, better treatment and even prevention of genetic diseases. In the area of basic science, the genomic information of human and other species will greatly help to understand the genomic organization, the control of gene expressions, cellular growth and differentiation and evolutionary biology.

9.1.6 Detection and treatment of some genetic diseases:

Medical and general researches have revealed about 4000 diseases of human with genetic basis. However, unlike infectious diseases, the genetic diseases affect between 1-2 percent of human population.

For a person to exhibit a genetic disease, the abnormal genetic material must usually be present in each of its cells, which means that it must also have been present in sperm or in egg or both from which the individual was derived. There are two ways in which this can happen. The first is that one or both parents carried a defect in their own genetic material; the second is that a mutation occurred during the formation of gametes.

Genetic diseases fall into three broad categories; **chromosomal abnormalities**, **unifactorial defects** and **multifactorial** defects. In the chromosomal defect (e.g. Down's Syndrome) a child is born with structurally or numerically abnormal chromosomes. Since a single chromosome contains many genes, this can lead to multiple disturbances and disorders. Unifactorial diseases (e.g. Huntington's diseases, cystic fibrosis, etc.) are caused by a single defective gene or pairs of genes. Multifactorial disorders (e.g. asthma, insulin dependent diabetes mellitus, etc.) are caused by the additive effects of several genes, alongwith environmental factors. Some examples of genetic diseases are discussed below:

Huntington's disease: It is due to an autosomal dominant allele on chromosome 4. The affected individuals are almost certainly heterozygous for the defective gene. Appearance of symptoms is usually delayed until the age of 40-50 years. The disease is characterized by progressive mental deterioration, which is accompanied by involuntary muscle movement. There is no treatment.

Cystic fibrosis: It occurs due to an autosomal recessive allele. It is characterized by a tendency to chronic lung infection and an inability to absorb fats and other nutrients from food. Most patients can be helped by daily physiotherapy for their lung problems, and periodic treatment with pancreatic extracts. Lab diagnosis is possible in this case.

9.1.7 Role of Biotechnology in the diagnosis of diseases:

Biotechnology is now playing a very important role in the diagnosis of infections as well as genetic diseases. The use of PCR (Polymerase chain reaction) and DNA probes is providing an excellent tool for the diagnosis of such diseases even before the onset of symptoms. Medical scientists can now diagnose more than 200 genetic diseases using such technologies. Through hybridization analysis, now it is possible to detect abnormal allelic forms of genes present in DNA samples.

Gene therapy:

One of the potential benefits of genetic engineering is to treat genetic diseases in individuals. Theoretically, it could be possible to replace or supplement the defective allele with a functional, normal allele. This could be inserted into the somatic cells of the child or adult or into the germ cells or embryonic cells.

The first illness likely to be treated by this technique is called **severe combined immuno deficiency disease** (SCID), which is characterized by a very poor immune system so the victim cannot resist infections and consequently die due to infections like pneumonia, influenza, etc. In this condition, the cells of the

bone marrow cannot produce an enzyme called **adenosine deaminase** (ADA).

In treating this SCID condition, the researchers will remove defective bone marrow cells from a patient, insert the normal gene for the ADA enzyme into those cells and return the cells to the patient's bone marrow. Thus the genetically altered body cells should produce their own ADA and provide the victim's body a normal immune response. Since this procedure would genetically alter bone morrow cells, but not the sex cells, so the patient could survive to reproduce but would then pass the defective gene and not the normal gene into the progeny.

Gene therapy of germ line cells is another matter, which has raised the complex issues of safety and ethics. In this type, recombinant DNA would be inserted into human sex cells so not only the treated individual be affected but so would all the individual's descendants.

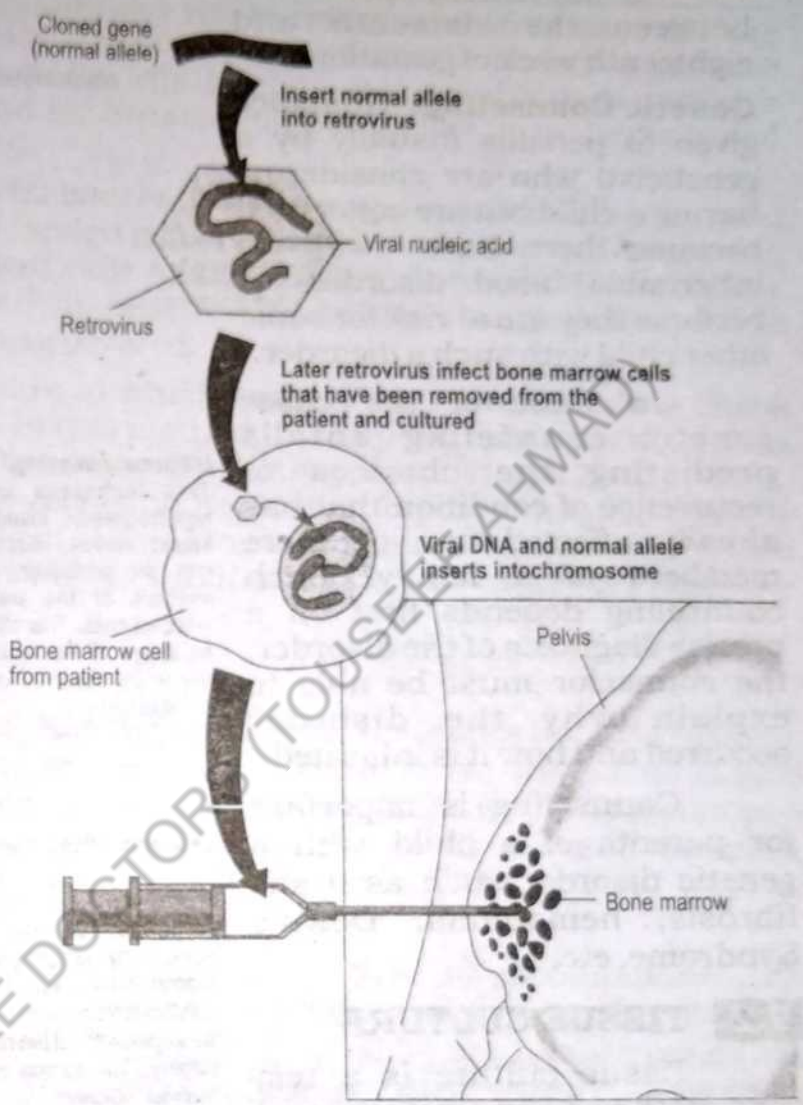


Fig: 9.6 One type of gene therapy

The approach has been developed to treat cystic fibrosis. In this treatment the cloned healthy genes wrapped in microscopic lipid envelopes (liposomes) solution would be periodically sprayed on the surface of lung epithelia of the diseased individual where normal mucus production is failed due to a defective gene. Application of this solution is made by means of an aerosol spray. The expectation is that liposomes packages will be taken up into the cells of the lungs surface and the genes may enter the chromosomes and be expressed. In animal traits this technique has shown success.

Amniocentesis: It is a diagnostic procedure in which a small amount of amniotic fluid is withdrawn from the amniotic sac, the membrane that encloses the fetus in the uterus. The amniotic fluid contains cells and chemicals from the fetus that can be analyzed to detect fetal abnormalities such as Down's syndrome, haemophilia, Tay-Sachs disease, etc.

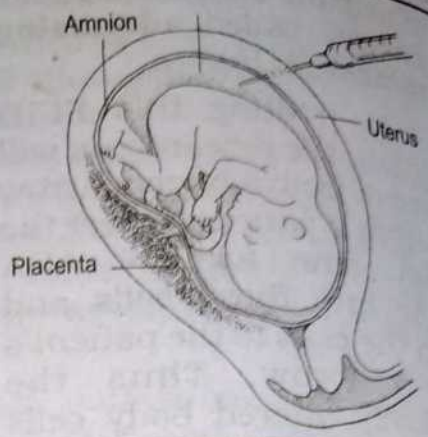
It is usually performed between the sixteenth and eighteenth week of gestation.

Genetic Counseling: Guidance given to persons (usually by a geneticist) who are considering having a child but are concerned because there have with an inheritable blood disorder, or because they are at risk for some other child with such a disorder.

In most of the cases genetic counseling entails predicting the chances of recurrence of condition that has already affected one or more members of a family. Such counseling depends first on a precise diagnosis of the disorder; the counselor must be able to explain why the disorder occurred and how it is inherited.

Counseling is important for parents of a child with a genetic disorder such as cystic fibrosis, hemophilia, Down's Syndrome, etc.

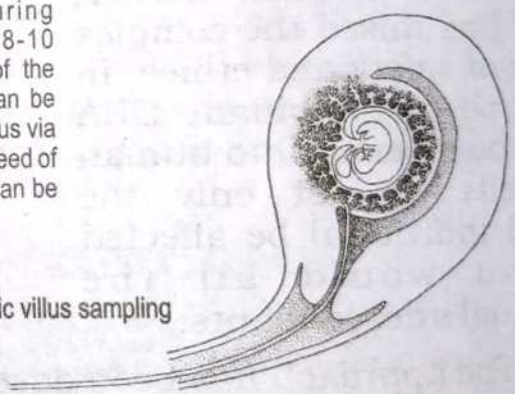
Amniocentesis



Ultrasound Imaging: This technique uses high-frequency, inaudible sound waves, directed into the abdomen and analysis of the waves reflected back. This allows an image of the fetus in *situ* to be observed on a monitor.

Ultrasound scan of the womb, showing the head of the fetus at 25 weeks

Chorionic villus sampling: From early on during pregnancy (within 8-10 weeks) tiny samples of the chorion (fetal tissue) can be withdrawn from the uterus via the vagina without the need of surgery. This sample can be analysed quickly.



Chorionic villus sampling

Fig: 9.7
Embryo development examining techniques

9.2 TISSUE CULTURE

Tissue culture is a test tube method used to create and clone novel plant varieties. A method in which whole plants grow by culturing small pieces of tissues cut from the parent, or even single parenchyma cells on an artificial medium containing nutrients. Plant cells are **totipotent** (a cell with full genetic potential of organism). In 1950 a carrot was produced by Frederick Steward from a single carrot phloem cell, which was grown in nutritive medium containing sugar, minerals and vitamins with coconut milk (having hormones cytokinin). The cultured cells divided to form an undifferentiated callus. When the hormonal balance is manipulated in the culture medium, the callus can sprout shoots and roots with fully differentiated cells. This test-tube plantlets can then be transferred to soil where they continue their growth. A single plant can be cloned into thousand of copies by subdividing calluses as they grow. This method is used for propagating orchids and also for cloning pine trees that deposit wood at unusually fast rates.

Cultured plants of certain plants give rise to embryo like structures that are smaller and simpler than plantlets. They are called **somatic embryos** because they are derived asexually from somatic cells. Somatic embryo of certain vegetable like tomato, celery, asparagus and for ornamental plants like lilies, begonia and African violets have been developed.

Plant tissue culture also facilitates genetic engineering in plants. Most techniques for the introduction of foreign genes into plants require the use of small pieces of plant tissue or single plant cells as the starting material. Tissue culture makes possible to regenerate genetically altered plants from a single plant cell into which the foreign DNA has been incorporated.

Another type of tissue culture in which anthers are cultured in a artificial medium is called **anther culture**. In this method, the haploid tube cells within the pollen grains divide, producing proembryos consisting of as many as 20 to 40 cells. Finally, the pollen grains rupture releasing haploid embryos. A haploid plant is produced from it. Now the doubling of chromosomes occurs. In other words we can say that anther culture is a direct way to produce plant that expresses recessive alleles.

9.2.1 Cloning:

As we have already studied that the cloning is the production of duplicate copies of genetic material, cells or entire multi-cellular living organisms occurs naturally in environment. These copies are referred to as **clones**. Some common examples are identical twins, asexual reproduction in plants and animals, regeneration and development of tumors, and cancers are the natural ways of cloning.

Artificial cloning is now possible by the method of recombinant DNA technology. It was believed since long time that adult vertebrate animals could not be cloned. Although each cell contains a copy of all genome but few are turned on while others remained off due to which differentiation occurs. Cloning of an adult vertebrate requires that all genes of an adult cells be turned on i.e. it should be totipotent. This totipotent cell can develop normally into new vertebrate individual. In 1997, scientist of Roslin Institute of Scotland became successful to develop a cloned sheep called **Dolly**. Since then calves, cats and goats have been cloned. Now the scientist can clone mammals but in most of the countries cloning of human is prohibited.

9.2.2 Some uses and applications of biotechnology in agriculture and medicine:

Biotechnology brings revolution in the field of agriculture, medicine and other fields of biological sciences. One of the most important advantage of biotechnology is that it allows mass production of proteins, which were difficult to obtain in past. Another field of biotechnology is the production of hormone. Human growth hormone produced by biotechnology is used to treat dwarfs. Insulin also produced by biotechnology is being used to treat diabetics.

The proteins which are being produced by Biotechnology give the hope that some troublesome and serious diseases like hemophilia can be treated

successfully. Clotting factor VIII will be available for hemophilia, human lung surfactant will be available for premature infants with respiratory distress syndrome.

Biotechnology also contributes to diagnosis by making DNA probes available. A DNA probe is a specific sequence of single stranded DNA, often radioactive, which binds by complimentary base pairing to a gene of interest.

Vaccines were made from treated bacteria or viruses, because both have surface protein. A gene for just one of them can be placed in plasmid to make rDNA. The bioengineered bacteria can produce many copies of these surface proteins. These copies can be used as a vaccine. A vaccine of hepatitis B has been made by this method.

Cotton, corn, potato and soybean plants have been engineered to be resistant to either insect predation, or herbicides, which are also environmentally safe. In 1999 transgenic crops were grown on more than 70 million acres around the world.

Biotechnology also made same progress in enhancing food quality of crops like soybeans developed, which mainly produces oleic acid, an unsaturated fatty acid. These transgenic plants also produce vernolic acid and ricinoleic acid, derivatives of oleic acid can be used as hardner in paints and plastics. These plants were developed by transforming gene from vernonia and castor bean seed into soybean genomes.

9.2.3 Some worries about biotechnology:

As we have discussed that biotechnology brings a revolution in biology, it brings so many benefits for mankind but on the other side DNA technology raised questions about possible dangers of this technology. The earliest concerns were that genetic manipulations of microorganisms could create hazardous new pathogens, which might escape from the lab.

With new medical products the main cause of concern is the potential for harmful side effects, both short term and long term. These products passed through exhaustive tests in laboratory before coming to market.

There is also a debate on this burning topic that genetically engineered agricultural products because of the potential dangers of introducing new organisms into environment. Some scientist argue that transegenic organisms are only extension of traditional cross breeding or hybridization e.g. the tangelo (tangerine-grape fruit hybrid) and buffalo (a cow-buffalo hybrid). No hybrid crop or animals were tested for safety before they were marketed.

There is another worry that food produced by recombinant technology will contain new proteins that are toxic or that cause severe allergies in some people. There is also concern that genetically engineered crop plants could become "superweed". Plants resistant to herbicides or microbial diseases and pest insects could escape into wild, and over grow, can pass genes to neighbour wild area and pollinate with wild one and will become difficult to control.

DNA technology has ethical debate with reference to human genome. At one hand, it opens a door for significant advances in gene therapy. On the other hand, it also raises significant ethical questions. Who should have the right to examine

someone else's gene? How should that information be used? Should a person's genome be a factor in suitability for job or eligibility for insurance? Ethical consideration as well as concerns about potential environmental and health hazards will likely slow the application of the products of biotechnology. The power of biotechnology, our ability to use and rapidly alter species demands that we proceed with humility and caution.

KEY POINTS

- The recombinant DNA technology leads us into the major growing industry the Biotechnology.
- Genetic engineering is the manipulation of genetic material of any organism.
- Vector is a DNA molecule into which a gene is inserted to construct a recombinant DNA molecule.
- Plasmids are small circular extra chromosomal DNA molecules.
- Gene sequencing provides the fastest way of determining the nucleotide sequence of genes.
- Restriction enzymes cut the DNA into small pieces at specific sites.
- Electrophoresis is a technique to separate molecules on the basis of their size, shape and rate of movement.
- Some human DNA does not code for proteins and repeated frequently, it is called DNA fingerprints.
- Culture of preferred genes carrying vecters of a species in a preferred environment is called genomic library.
- Genetic diseases fall into three broad categories.

EXERCISE

1. Encircle the most correct choice:

i) The enzyme used to seal the DNA is

a) Restriction enzymes b) Ligase

c) Polymerase d) All of these.

ii) The enzymes that act like scissors in recombinant DNA technology are:

a)Ligase b) Restriction enzymes

c) Polymerase d) None of these

iii) If the sequence of nucleotides on mRNA template is AUCGUA then the sequence of newly synthesized DNA strand would be
a) UAGCAU b) AUCGUA c) TAGCAT d) TTCGTT.

iv) Multifactorial defects refers to
a) One gene b) Many genes
c) Many genes and environmental factors
d) Chromosomal abnormality.

v) Which of the following can serve as vector?
a) Plasmid b) Bactoriophage
c) Both a and b d) None of these

vi) The non coding sequences of gene are
a) Codon b) Exon c) Intron d) None of these

vii) In syntherizing DNA strand from RNA, the enzyme involve is
a) RNA polymerase b) DNA polymerae
c) Ligase d) Reverse transcriptase

viii) The approximate no of human genes is
a) 10000 to 15000 b) 20000 to 25000
c) 30000 to 35000 d) 40000 to 45000

2. Write detailed answers of the following questions:

i) Discuss the various steps involved in recombinant DNA technology.

ii) State and explain some applications of genetically engineered bacteria.

iii) Explain some genetic diseases and their treatment. How they occur?

iv) What is gene therapy? How it is helpful in treating diseases? Explain.

v) Discuss some uses and applications of biotechnology. What could be its potential dangers?

3. Write short answers of the following questions:

I) Define biotechnology, genetic engineering and HGP.

ii) What are restriction enzymes, DNA polymerases and ligases.

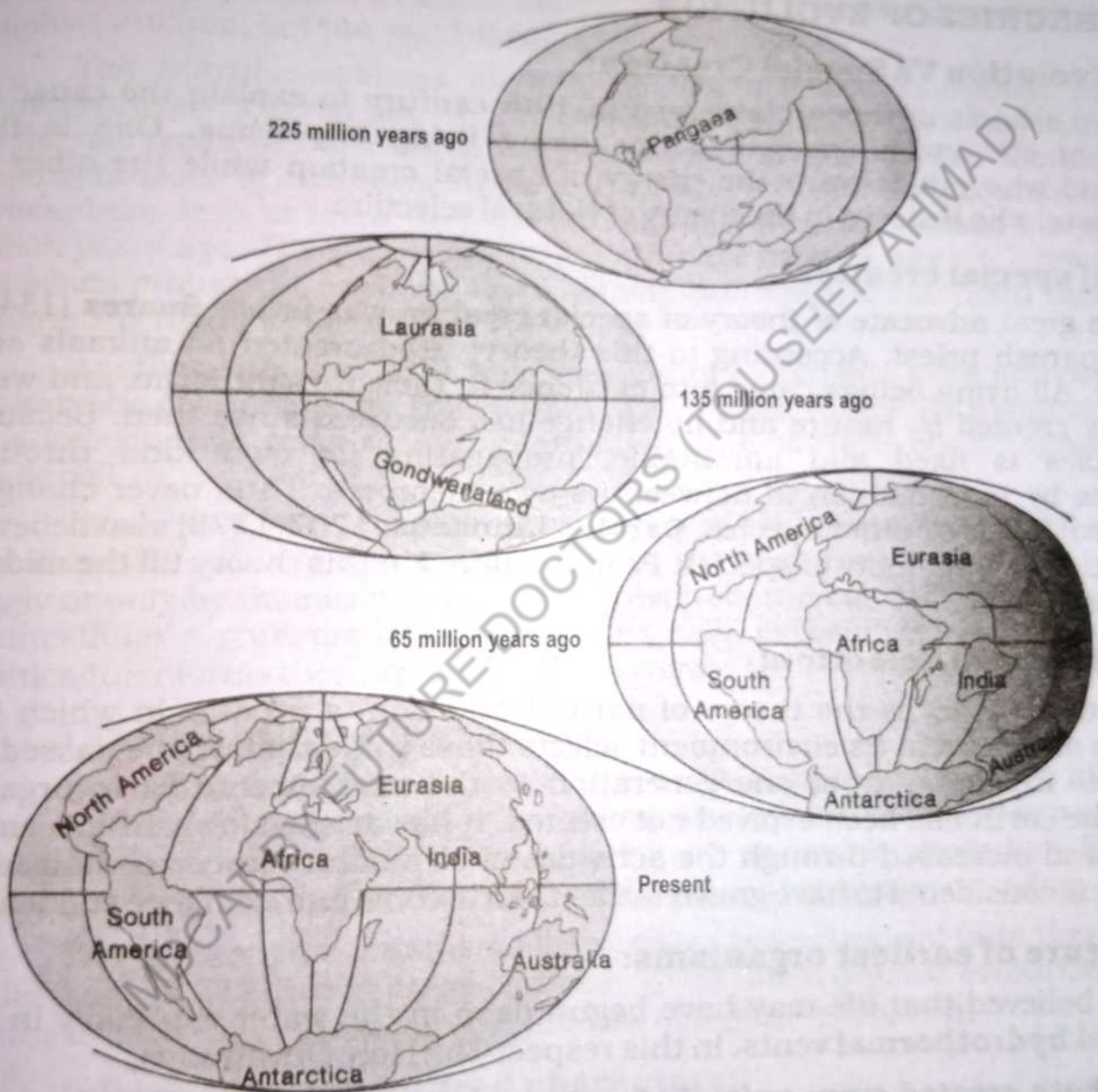
iii) What is meant by sticky end.

iv) What is the importance of plasmids in recombinant DNA technology.

v) What are DNA fingerprinting; Gel electrophoresis and genomic library.

CHAPTER 10

EVOLUTION



Members of various populations, during the course of many generations, go through changes in characteristics. Such changes must occur in the genetic constitution of the population and ensure the emergence of new species. The phenomenal continental drift shown here has dramatically affected the process of evolution.

The word 'evolution' refers to the gradual development of something e.g evolution of earth, evolution of man, evolution of plants and so on and so forth. The evolution with reference to plants or animal or both is referred to as **organic evolution**. Broadly, evolution can be said to be the development of an entity in the course of time through gradual sequence of changes from simple to complex state. **Darwin** defined it as "descent with modification". According to **Zimmermann** (1953) evolution is the transformation of the form and mode of existence of an organism in such a manner that the descendants differ from their ancestors.

10.1 THEORIES OF EVOLUTION

10.1.1 Evolution Vs Special Creation:

Two schools of thought emerged in 19th century to explain the cause of diversity of life and interrelationship among living organisms. One is the creationists who put forward the theory of special creation while the other is evolutionists, who believed in the theory of Natural selection.

Theory of special creation:

The great advocate of theory of special creation was father **Suarez** (1548-1613), Spanish priest. According to this theory; "God created all animals and plants" i.e. All living beings came into existence in their present forms and were specifically created by nature and no change has occurred since then. Because each species is fixed and immutable, propagating its own kind through generations by reproduction in between its own members. Thus never changed into different kinds or other species. **Carolus Linnaeus** (1707-1778) also believed in divine creation and fixity of species. People believed in this theory till the middle of 19th century.

Theory of Natural Selection:

Another theory is the theory of natural selection, a process in which the fittest of an organism in its environment selects those traits that will be passed on with greater frequency from one generation to the next. According to organic evolution the earth has been evolved not created. It has arisen slowly from a small beginning and increased through the activities of elementary forces contained in itself. So life is considered to have grown rather than to come into existence suddenly.

10.1.2 Nature of earliest organisms:

It is believed that life may have begun deep in the water especially in hot spring called **hydrothermal** vents. In this respect The Holy Quran says;

"Allah hath created every animal of water. Of them is (a kind) that goeth upon its belly and (a kind) that goeth upon two legs and (a kind) that goeth upon four. Allah createth what He will. Lo! Allah is Able to do all things".

(Sura Al-Nur, Ayah 45)

These vents could have supplied the energy and raw material for the origin and survival of early life forms. A group of bacteria called archaebacteria can

tolerate temperature, upto 120°C. It is also believed that the most primitive organisms lived in an environment abundant in complex compounds. They had a metabolism which was of catabolic nature, to release the energy stored in those compound. However, when the supply of these compounds with high energy became reduced in the environment, the necessity of efficient anabolic activities became evident. Therefore, the simplest organisms like bacteria which were evolving, explored possible source of energy. Thus several types of respiratory reactions, which were correlated with nutritive systems exploited by bacteria, came into existence. With regard to nutritive systems, the heterotrophic bacteria evolved first and than the autotrophic bacteria. The autotrophs obtained energy from chemical reactions in which simple inorganic compounds were involved e.g sulphur and Iron, but the yield of energy was much lower.

The nutritive systems of both the bacteria are immensely inferior to photosynthesis of green plants. The evolution of photosynthetic mechanism may be the real basis for the evolution of all green plants. The oxygen liberated during photosynthesis by the decomposition of water began to accumulate in the atmosphere. It is believed that the prokaryotes may have arisen more than 1.5 billion years ago. The eukaryotic cell might have evolved when a large anaerobic amoeboid prokaryote ingested small aerobic bacteria and stabilized them instead of digesting them.

Another hypothesis for the evolution of eukaryotic cells propose that the prokaryotic cell-membrane folded inward to enclose copies of its genetic material. This invagination resulted in the formation of membrane bound organelles in a single cell.

In any way, development of eukaryotic cell led to increase in the complexity and diversity of life-forms on the earth. In the beginning these eukaryotes lived singly or only by themselves. Later some evolved into colonial form which became mulitcellular organisms in which various cells especialized into tissues. These multicellular forms then adapted to life in a great variety of environment.

10.1.3 Theory of organic evolution:

According to this theory, species are not immutable but once life appeared on earth, it slowly evolved i.e. a species may slowly have changed into new species, whether its original stalk (species) may persist or vanish altogether. Evolutionsts believe that evolution has occurred in the past and is even going on today.

The concept that organisms living today have changed from those that lived in the past, i.e. the living things can change, is called organic evolution. Following are the theories, which explain the process of organic evolution.

1. Inheritance of acquired characters:

Jean Baptiste de Lamarck (1744-1829) was a great French Zoologist and a pioneer evolutionist of the pre-Darwin period.

In his book **Philosophie Zoologique** published in 1809, he elaborated a new theory of organic evolution based on the principle of use and disuse of organs. **Lamarckism** (Lamarckian Theory) is now considered as **Inheritance of acquired characters**.

His theory was based on following postulates:

(I) Effects of environment

(ii) Use and disuse of organs.

(iii) Inheritance of acquired characters.

(i) Effects of environment:

Lamarck believed that evolution of new types takes place due the effect of the environment. Some animals under changed conditions of environment came across new needs and as such acquire new characters (new organs) to better meet with the changed situation of food habit, physiology or shelter seeking.

(ii) Use or disuse or organs:

In order to satisfy these new needs, organisms use some organs persistently and disuse others. So the efforts of an individual of greater use and total disuse of organs strengthens and develops an organ and disuse results in its degeneration and ultimate disappearance.

Lamarck believed that the accumulation of such small changes through successive generations promote the development of new organs or characters, which are transmitted to the offspring in the next generation. This is called Inheritance of acquired characters.

(iii) Inheritance of acquired characters:

Lamarck believed that once made, these adaptations called acquired characteristics are transmitted from generation to generation. So new generations show new characters with the development of some new organs on the basis of use and disuse of organs.

Lamarck cited numerous examples to illustrate and support his evolution theory.

Evolution of Giraffe: The horse-like ancestors of the giraffe, when migrated to Africa were forced to feed upon the foliage of tall trees. The continuous effort of stretching their necks and fore limbs to reach the tall trees, restricted in an increase in length of those parts, which were inherited by the offspring of the next generation. Thus, through successive generations, the present day giraffe has enormously elongated neck and forclimbs.

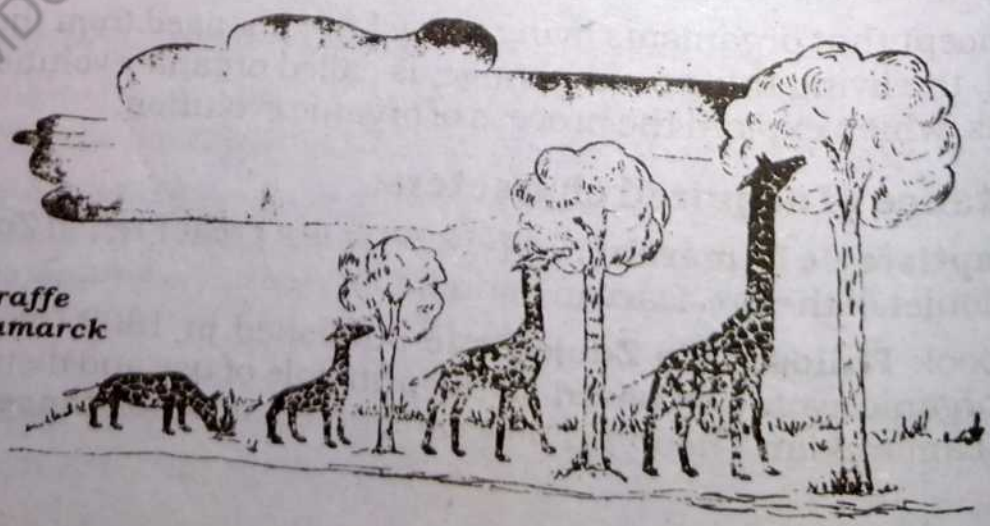


Fig: 10.1
Evolution of Giraffe according to Lamarck

Evolution of Snake: In order to escape the attacks of many mammals, the lizard-like ancestors of snakes developed the habit of gliding over the ground, creeping through narrow fissures and holes. As a result, after a large number of generations, their bodies elongated and their limbs disappeared due to disuse.

Lamarck also gave other examples like: Evolution of Kiwi, Evolution of foot of modern horse, Evolution of webbed feet of duck, Evolution of loss of teeth in whale, etc.

Objections on Lamarckian theory:

Although experimental evidence proved the first two points of the Lamarckian theory, the third point i.e. inheritance of acquired characters, however, did not seem to be operating in the process of evolution..

The transmission of acquired characters is crucial factor to the theory given by **Lamarck**. Many objections were put forth against this hypothesis.

1. Mutilations as a result of accidents or diseases are not inherited.
2. Boring of holes in ears and nose in mothers is not inherited in new born child.
3. Many human families observe circumcision ceremony in infant males since thousand of years, despite that every baby boy in each generation is born with a fore-skin. This proves that acquired characters are not inherited.
4. The greatest set back to Lamarckism was **Weismann's** theory of germinal continuity in 1892. He was a German Biologist.

2. Weismann's theory (Germinal continuity theory):

As a result of fusion of male and female gametes the zygote is achieved. This zygote during its development gives rise to two types of cells.

(a) Somatic cells, which differentiate into various tissues, and form different organs of the body.

(b) Germ cells, a few cells remain undifferentiated, which later on give rise to egg cells or sperm cells.

As the new organism arises only from the germ cells, any change that occurs during its lifetime in soma is called acquired and such changes can not be transmitted to the offspring, as the soma is not concerned with reproduction.

Weismann strongly opposed and rejected Lamarckian theory on the basis of his experiments during which he removed the tails of mice for repeated generations. The tails always appeared in every new generation in full length.

3. Theory of Natural selection:

Darwin sailed around the world investigating nature's diversity i.e. plants, animals and geological formations. He wrote a book **the origin of species** published in 1859, in it he gave **the theory of organic evolution** based on natural

selection, therefore called theory of **Natural Selection**. Important features of this theory are:

(i) Over reproduction:

It is a matter of common observation that all organisms usually have very high reproductive rate or we can say they are very fertile, giving rise to much higher number of offspring that can possibly survive in their habitat. For example a single codfish lays 5 to 7 millions eggs in a single season. A house-fly lays about 120 eggs six times in every summer. Starfish produces a million eggs in a year. A rabbit breeds at the age of six months, giving six youngs in a litter and four litters in a year. The slowest breeder like Elephant in its life time about 100 years, with an active breeding period of sixty years produces about six offsprings.

It is obvious that, if such rates of reproduction were to continue even for a few generations, soon a single species will occupy almost the whole area of the habitat and as such no space, food and other necessities of life will be available for any other species to exist. But we see that the total number of each species remains almost stationary or we can say within limits, which is due to the struggle for existence.

(ii) Struggle for existence:

A logical result of over production is the severe competition for food and space and other necessities of life, what Darwin called **the struggle for existence**. This struggle may be of three categories.

(a) Intra specific struggle, between the individuals of same species having similar needs.

(b) Inter specific struggle, among the members of different species.

(c) Environmental struggle, struggle against the extreme forces of nature e.g: drought, rain, cold and lightening.

Only those members of species, which achieve adulthood after passing this struggle, may be able to reproduce.

(iii) Variations and Heredity:

Individuals of a population vary in their ability to exploit the available resources of nature and no two off spring of the same parents are exactly alike.

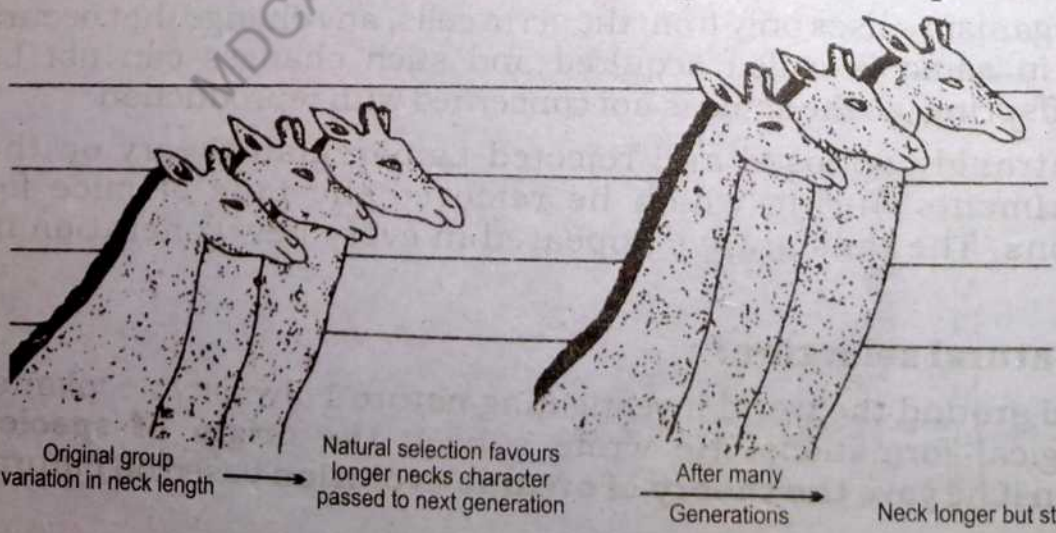


Fig: 10.2 Darwin's Giraffe

These minor variations are one of the innate property of all living things. Organisms with variations that better equip them to survive in a particular environment, will be favoured over others that are less adapted. In this way nature will select such organisms for future propagation and continuity of their generation.

(iv) Natural selection or survival of the fittest:

Darwin termed these phenomena as the survival of the fittest or natural selection and this is the core of Darwin's theory of organic evolution.

Darwin believed that natural selection is the driving force behind the evolution. Darwin's idea of Natural Selection was based on the practice of Artificial selection, which has been used for thousands of years by plant and animal breeders to produce strains of crop plants and domestic animals.

In practice, offsprings with desirable traits are selected from each generation for breeding purposes, while offsprings lacking such traits are prevented from reproduction. Breeder continue selecting a particular direction generation after generation, until the desired results are achieved.

According to Darwin, the environment plays the role of the breeder in Natural selection, which generates populations whose members are better adapted (most fit) to the environment and the species that lack the ability to cope with environmental changes will shrink in number or even become extinct.

(v) Formation of new species:

Darwin's view of natural selection is that most evolution occurs in small adaptive steps i.e. evolution proceeds gradually. Moreover some organisms show variations in one direction and others in other direction due to different environmental conditions in which they live and try to survive.

Continuation and accumulation of these divergences or variations gradually produce new and different types and in time it leads to the creation of large groups/new species; which Darwin called as **origin of species**. The Holy Quran also explains the doctrine of the formation of new species in a unique style.

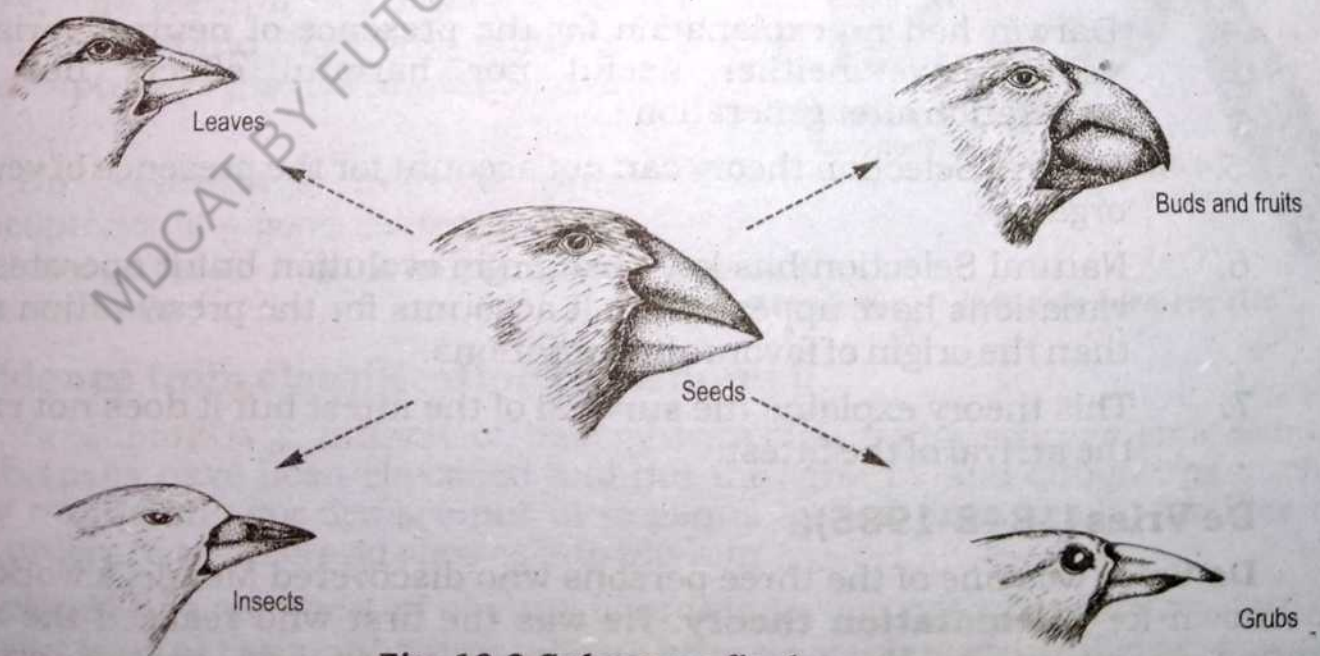


Fig: 10.3 Galapagos finches

"Have they not seen how We have created for them of Our handiwork the cattle, so that they are their owners. And have subdued them unto them, so that some of them they have for riding, some for food?

(Sura Ya-sin, Ayah 71-72)

Summary of Charles Darwin Theory:

The theory of organic evolution was given by Charles Darwin in his famous book "The origin of species" published in 1859. The chief points of his theory are:

1. There is always a tendency of over reproduction in a species.
2. All individuals of a species are not 100% alike i.e. there are variations. He assumed that variations are inherited.
3. There is intra-specific competition among the individuals in a species and inter-specific competition between the different species and to environmental changes. This is collectively called as struggle for existence.
4. In the struggle for existence, the favourable variations will survive and the unfavourable will be exterminated. This results in the survival of the fittest.
5. The favourable variations will accumulate and this natural selection will lead to gradual changes in the characters of a species towards better adaptation. Thus vast gradual changes will result in the origin of a new species.

Objections to Darwin's Natural selection theory of organic evolution:

Darwin's theory of natural selection was so reasonable and well supported by arguments and evidences that it was soon accepted by many biologists, yet some of them objected as under:

1. Darwin did not clearly differentiate between heritable and non-heritable variations.
2. He emphasized the role of minor variations but not the mutations which appear suddenly and without reference to the parents, really play an important role in evolution .
3. He could not tell the cause of variations.
4. Darwin had no explanation for the presence of neutral variations which have neither useful nor harmful effects but exist generation after generation.
5. Natural Selection theory can not account for the presence of vestigial organs.
6. Natural Selection has key position in evolution but it operates after variations have appeared, so it accounts for the preservation rather than the origin of favourable variations.
7. This theory explains the survival of the fittest but it does not explain the arrival of the fittest.

4. De Vries (1848-1935):

De Vries was one of the three persons who discovered Mendel's work, he is also known for his **mutation theory**. He was the first who realized the role of mutation in evolution. He proposed that new races and species originate

discontinuously and non-gradually. He called mutation as discontinuous variation due to which permanent racial changes occur. Mutations are sudden heritable changes. They occur in organisms in unpredictable directions. They are not caused by environmental effects or cross-breeding. De Vries suggested that mutation affected a change in the nature of germ cells while fluctuation was because of the effect of environment. He thought that permanent changes take place spontaneously out of the internal conditions and are not necessarily adaptive to nature. Majority of them get destroyed. Only those mutations that are adaptive survive in nature. The credit goes to De Vries for indicating that mutations are the source of variability on which natural selection acts.

10.2 EVIDENCES IN FAVOUR OF ORGANIC EVOLUTION

For a theory of evolution and its importance, tremendous evidence is needed for its acceptance. Following evidences are collected from wide variety of different fields.

1. Evidence from fossil record (Paleontology):

A fossil is any trace of life from the past. Fossil record consists of an entire collection of such remains from which paleontologists attempt to reconstruct the biology of the organisms whose remains were left behind.

Example: Archaeopteryx (Archaeo = old, pteryx = wing), fossil bird was discovered in 1861 in Bavaria (Germany). This bird had lived 150 million years ago. Unlike the modern birds, Archaeopteryx had teeth, a long tail having 20 vertebrae, wings containing movable fingers with claws. All these characteristics show link with reptiles. The teeth of this pigeon/crow sized animal would have been suitable for the capture of insects or other small prey.

So scientists believe that Archaeopteryx is a good evidence of an evolutionary path way leading from reptiles to birds.

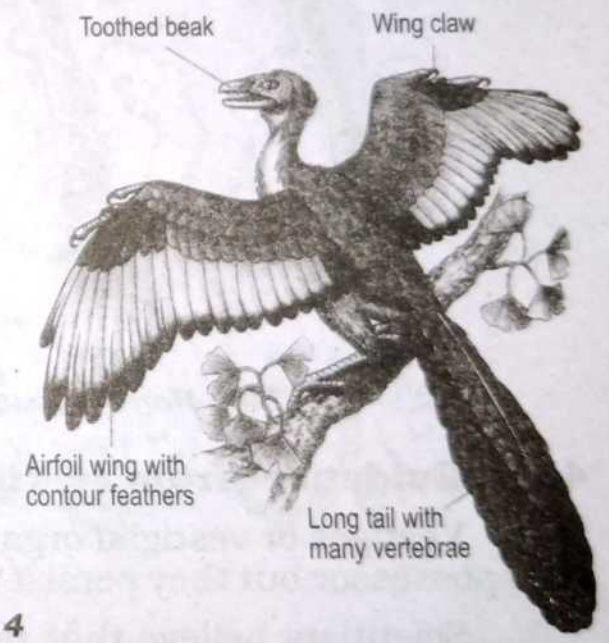


Fig: 10.4
Archaeopteryx, a jurassic bird-reptile

2. Evidence from classification (Taxonomy):

Taxonomy is a branch of biology in which various organisms showing resemblances have been classified and put into groups and subgroups such as closely resembling species are put in to genus, genera into family, families into order, orders in to class and classes into phylum.

Example: All the members of phylum chordata have a notochord, nerve cord and gill slits at least at their embryonic stage. These resemblances in different groups of chordates like fish, amphibians, reptiles, birds and mammals can be assumed because of their common ancestors in the past.

All vertebrates have similar pattern of organs, which indicate that they are related to one an other.

3. Evidence from homology (Comparative anatomy):

Many different species show close resemblance in their anatomy i.e. their internal general structural plan is same, though their external appearance is very different performing different functions. Such remarkably similar structures perform modified functions in different species are called **homologous organs**.

Example: Skeletal system in the wing of bird or bat, fore-limb of Turtle, fore-leg of horse, flipper of whale and arm of man is very similar internally having same type of bones and muscles though they all are superficially different from each other and perform different functions in different habitats.

Biologists are of the opinion that homology indicates their common origin.

Fig: 10.5 Homologous structures – anatomical signs of evolution

4. Evidences from vestigial organs (Vestiges):

Vestiges or vestigial organs are those which have ceased to be of any use to their possessor but they persist in reduced form generation after generation.

Scientists believe that these vestiges are retrogressive organs which were well developed and functional in their ancestors.

Many vertebrates possess structures with no function, but they resemble functional structures of other vertebrates. It suggests that their structures are inherited from a common ancestor.

Examples:

(i) In whales and snakes pelvic bones are present in reduced form though both have no hind-limbs for the attachment to these bones.

(ii) Wings of Kiwi and Ostrich are reduced and serve no useful function,

this proves that these flightless birds have descended from the birds with well developed wings.

(iii) Splint bones of foot of horse are the remnants of their toes.

(iv) Vestigial organs in man like:

- **Coccyx** is a tail bone (reduced tail) which is well developed in other vertebrates.
- **Vermiform appendix in man** is a small finger-like reduced caecum. It is a part of the digestive tract of many grazing mammals where cellulose is digested by microorganisms.
- **Nictitating membrane** is well-developed in birds to clean their eye ball but in humans it is highly reduced and folded performing no function.
- **Ear muscles** are well developed in dogs and horses helping them to move their pinna to collect sound waves from different directions. In human beings ear muscles are greatly reduced and non functional for this purpose.

Vestiges explain that natural selection accounts for the elimination of structures that are no longer needed by an organism exploiting a different way of life.

5. Evidence from comparative embryology:

Detailed comparative embryological study shows similarities between widely separated animal groups though such animals have markedly different adult forms and functions.

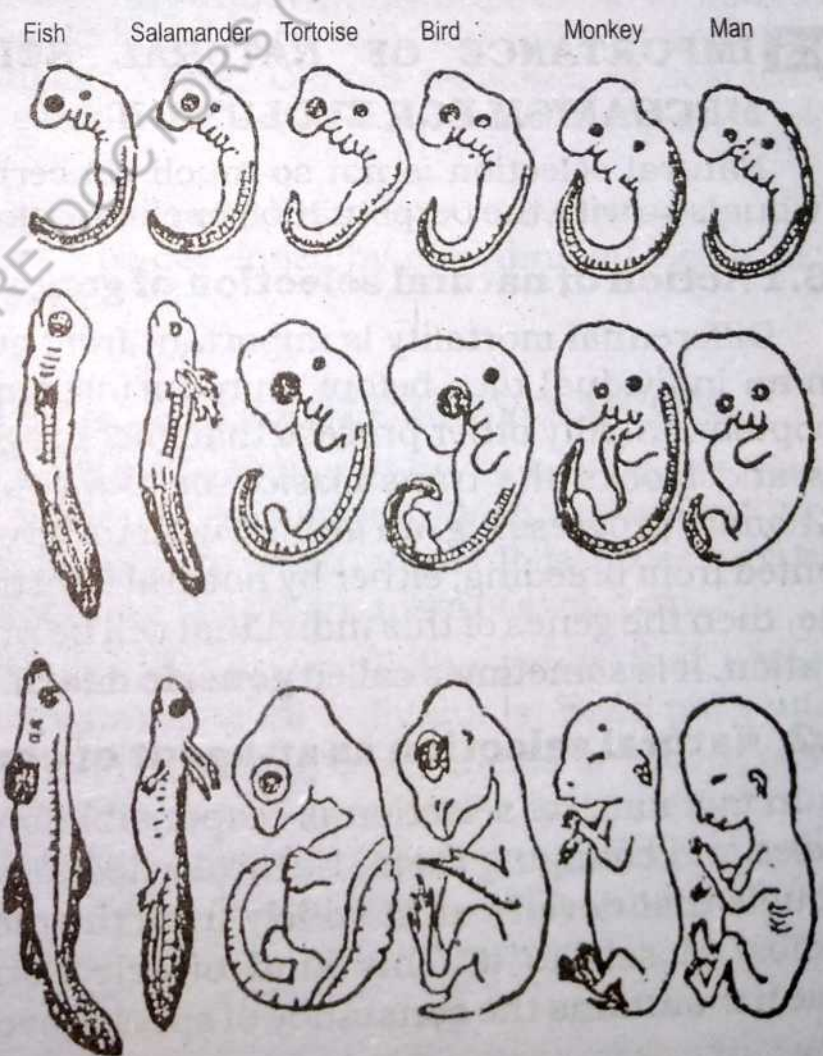


Fig: 10.6 Vertebrate embryos at three comparable stages of development

Example: Vertebrate history suggests that fish, salamanders, tortoises, birds and mammals including man had a common ancestor, probably some type of primitive fish, so embryonic development of all these animals provides a window to evolution. Scientists believe that the study of embryonic development provides one of the best tools to understand the evolutionary linkage among animals.

6. Evidence from Biochemistry:

The blood serum contains certain specific proteins which determine antigen-antibody reactions.

Example: Tests of blood sera have shown the protein relationship between Man and apes, to old world monkey and the new world monkey. The blood proteins of carnivores like cats, dogs and bears are closely related and those of herbivores like cow, goat, sheep and deer resemble mutually.

7. Evidence from domestication:

Domestication means artificial selection in breeding provides evidence for evolution.

Example: Vast diversity has been achieved in domestic dogs and pigeons by artificial selective breeding procedure over a short period of time by man. This is evidence that evolution is possible.

10.3 IMPORTANCE OF NATURAL SELECTION AS A POSSIBLE MECHANISM FOR EVOLUTION

Natural selection is not so much concerned with the survival or death of individuals as with the perpetuation or elimination of genes carried by them.

10.3.1 Action of natural selection of genes:

Differential mortality is important from evolutionary point of view because when an individual dies before reproducing, unfavourable genes eliminate from the population. Any other process that encourages the transmission of favourable genes and blocks the transmission of unfavourable genes contributes towards evolutionary progress e.g. an animal with unfavourable characteristics in any way prevented from breeding, either by natural infertility or become unsuccessful to get a mate, then the genes of this individual will be prevented from transmitting to next generation. It is sometimes called **genetic death**.

10.3.2 Natural selection as an agent of constancy as well as change:

In fact natural selection is responsible both for maintaining the constancy of species and changing them. Natural selection is most destructive against those individuals that deviate most widely from the mean, and is in favour of those that align most closely to it. This kind of selection is called **stabilizing selection** because it maintains the constancy of species over generations.

10.3.3 Natural selection and population genetics:

In producing long term evolutionary change the forces of natural selection do not merely act on an individual's gene, but on population.

A more or less genetically isolated unit of population is known as **deme**. The genetic constitution of a deme i.e. the sum total of all the different genes in population is known as **gene pool**. The evolutionary future of an individual organism depends on its genetic constitution. So the evolutionary future of an individual organism depends on its gene pool.

10.4 ARTIFICIAL SELECTION AND ITS ROLE

One line of evidence supporting evolution that particularly impressed Charles Darwin was **artificial selection**, i.e breeding of domestic plants and animals to produce specific desirable features. Man has modified some species over generations by selecting individuals with the **desired traits** as breeding stock. The plants and animals we grow and rear for food bear little resemblance to their wild ancestors. Various breeds of dogs provide a striking example of artificial selection. Dogs descended from wolves, and even today the two will readily cross-breed. With rare exceptions, a few modified dogs resemble wolves. Some breeds are so different from one another that they would be considered separate species if they were found in the wild. Interbreeding would hardly be possible without a lot of human assistance. If humans could breed such radically different dogs in a few hundred to at most a few thousand years, Darwin reasoned, it seemed quite plausible that natural selection could produce the varieties of living organisms in hundreds of million years.

Recombinant technology has opened the door of evolution by artificial selection. A number of varieties can be developed by providing artificialy selected genes rather than natural selection.

10.5 GENE FREQUENCIES AND THEIR ROLE IN EVOLUTION

Population genetics is a branch of genetics that deals with the frequency, distribution and inheritance of alleles in population. With these, evolution is a change in the genotype of population over generations. It is necessary to learn about population genetics to understand the mechanism of evolution.

The basic term, gene pool is defined as all the genes that occurs in a population i.e all alleles of all genes found in all individuals. Each particular gene can also be considered as gene pool, consisting of all alleles of that specific gene occur in population e.g. in a population of 100 pea plants the gene pool for flower colour would consist of 200 alleles. The relative proportions of different alleles for colours, is called allele frequency or gene frequency e.g. the gene pool for flower colour, is 140 allele for purple flower and 60 for white flower, then allele frequency would be, purple 0.7 (70%) and white 0.3 (30%).

Now the question arises what role gene frequency plays in evolution? Suppose a cow eat up all purple flowers before they produce seeds. The allele for

purple flowers (P) is dominant over white (p), allele (p) in the entire population is in the purple flowered plants (PP or Pp). None of these plants will grow while the white flowered plants reproduce only. The next generation will consist entirely of white flowered pea (pp). The gene frequency for purple will drop to 0% while for white flower will rise to 100%. As a result of selective eating habits of the cow evolution will have occurred in that field. It shows that evolution is a change in the allele frequencies of a population, owing to differential reproduction among organisms bearing different alleles. In evolutionary terminology the fitness of an organism is measured by its reproductive success i.e. in the given example white flower had greater fitness than purple flower because they produce more viable offspring.

10.5.1 Hardy-Weinberg Law and its implication:

In 1908, an English Mathematician **G.H.Hardy** and a German Physician **W.Weinberg** proposed relationship between the frequencies of alleles and genotypes in populations. This relationship is known as the Hardy-Weinberg Equilibrium. According to them "the frequencies of dominant and recessive alleles in a population will remain constant (unchanged) from generation to generation provided certain conditions exist". In other words, "under stable conditions allelic frequencies and their genotype ratios remain constant generation after generation."

They gave an equation which is expansion of the bionomial expression $(P+q)^2$, where P is the frequency of one allele and q is the frequency of another allele. So the formula for the **Hardy Weinberg** equilibrium is ;

$$P^2 + 2pq + q^2 = 1$$

Let us examine our hypothetical population in which allele 'A' has a frequency of 0.9 and allele 'a' has a frequency of 0.1.

By substituting the allelic frequencies 0.9 and 0.1 for P and q respectively. We have

$$P^2 + 2pq + q^2 = 1$$
$$(0.9)(0.9) + 2(0.9)(0.1) + (0.1)^2 = 1$$
$$0.81 + 0.18 + 0.01 = 1$$

If we calculate the frequencies of all possible genotype they should be 1.

P^2 = frequency of A/A = 0.81

2 pq = frequency of A/a = 0.18

q^2 = frequency of a/a = 0.01

Total 1.00

This stability is referred to as genetic equilibrium. A deme remains unchanged in its overall characteristics and no evolution occurs. Evolution only takes place if and when the genetic equilibrium is upset as a result of mutation, environmental change and natural selection.

certain factors can upset the genetic equilibrium and bring about evolutionary change, firstly, a gene may be lost altogether from population as a

result of pure chance. This is expected to produce significant change in small population.

The second factor that may cause genetic drift depends on the fact that the neighbouring populations may not necessarily be totally isolated from each other. In this way a population may gain or lose gene, thereby altering its genetic composition.

10.6 ENDANGERED SPECIES

One of the most prominent features of the history of life on earth has been the periodic occurrence of major extinctions. During the course of geological time there have been five such events, in each of which a large proportion of the organisms on earth at that time became extinct. Major extinction clearly produces conditions appropriate for rapid evolution for those relatively few plants, animals and micro organisms that survive the extinction process.

Another phenomenon is the competition between individuals of two or more species for the same resources which limits their population size. More than 70 years ago, the soviet ecologist **G.F. Gause** formulated what is called 'the principle of competitive exclusion'. This principle states that if two species are competing with one another for the same limited resource, then one of the species will be able to use that resource more efficiently than the other, and the former will therefore eventually eliminate the latter locally. The former populations which are in a threat of elimination are called endangered species. In recent years, however, the threat to the welfare of wild plants and animals has increased dramatically mostly as a result of modernization. Tropical rain forests, the most threatened area on the earth, have been reduced to 44% of their original extent. Accurate estimation of the number of extinction is impossible in areas like rain forests, where taxonomists have not even described most species.

Other causes of extinction include climatic change, pollution and invasion of foreign species. Habitat other than rain forest, i.e grasslands, marshes, deserts and deep sea are also threatened.

In Pakistan, Cheetah, Tiger, Asian lion, Indian rhino, Cheer pheasant, Gazzal have been declared extinct. While Indus dolphin, Blackbuck, Crocodile, Leopard, Great Indian bustard, Houbara bustard, White headed duck and Marbled teal are among the animals near to extinction.

Conservation of habitat as well as endangered species are required. Conservation plan must include the following components.

1. A global system of national parks to protect large tracts of land and build life that allow movement between natural areas.
2. Protection of landscapes that allow controlled activity.
3. Zoo's, Safaris, and botanical gardens to save species whose extinction is imminent.

KEY POINTS

- Hardy-Weinberg gave relationship between the frequencies alleles and genotypes in populations.
- Lamarck's theory of organic evolution based on use and dis use of organs.
- Lamarck believed that acquired characters are transmitted to new generation.
- Four main features of Darwin's theory are over production struggle for existence, variation and heredity and natural selection or survival of the fittest.
- Archaeopteryx is believed to be evolutionary path way leading from reptiles to birds.
- Coccyx, vermiform appendix, nictitating membrane, ear muscles are vestigial organs found in Man.

EXERCISE

1. Encircle the most correct choice:

i) The struggle for existence between the individual of same species having similar needs is

(a) Inter specific struggle (b) Intra specific struggle
(c) Environmental struggle (d) Intra specific association

ii) The book written by Charles Darwin is

(a) Origin of species (b) Philosophie Zoologique
(c) Principle of competitive exclusion
(d) Organic evolution

iii) Archaeopteryx is believed to be evolutionary pathway leading from

(a) Amphibian to reptiles (b) Reptiles to birds
(c) Reptiles to mammals
(d) Echinodermates to chordates

iv) Which of the organ is a not vestigial organs found in man

(a) Coccyx (b) Vermiform appendix
(c) Eye lids (d) Ear muscles

v) Hard-Weinberg gave relationship between the frequencies of alleles and genotype of
(a) An individual (b) Population
(c) Species (d) All of them

vi) Lamarcks theory based on following points except.
a) Effects of Environment b) Use and Disuse of organs
c) Natural Selection d) Inheritance of acquired characters.

vii) Germinal continuity theory was proposed
a) Hutton b) Lamarck
c) Weismann d) Darwin

2. Write detailed answers of the following questions:

i) What is organic evolution, describe in detail the mechanism of evolution.

ii) Describe Lamarck's theory of organic evolution, give various examples and also objections to this theory.

iii) Describe in detail the main features of Charles Darwin's theory of natural selection.

iv) Describe various evidences in support of organic evolution.

3. Write short answers of the following questions :

i) What is Hardy Weinberg principle? Describe it briefly.

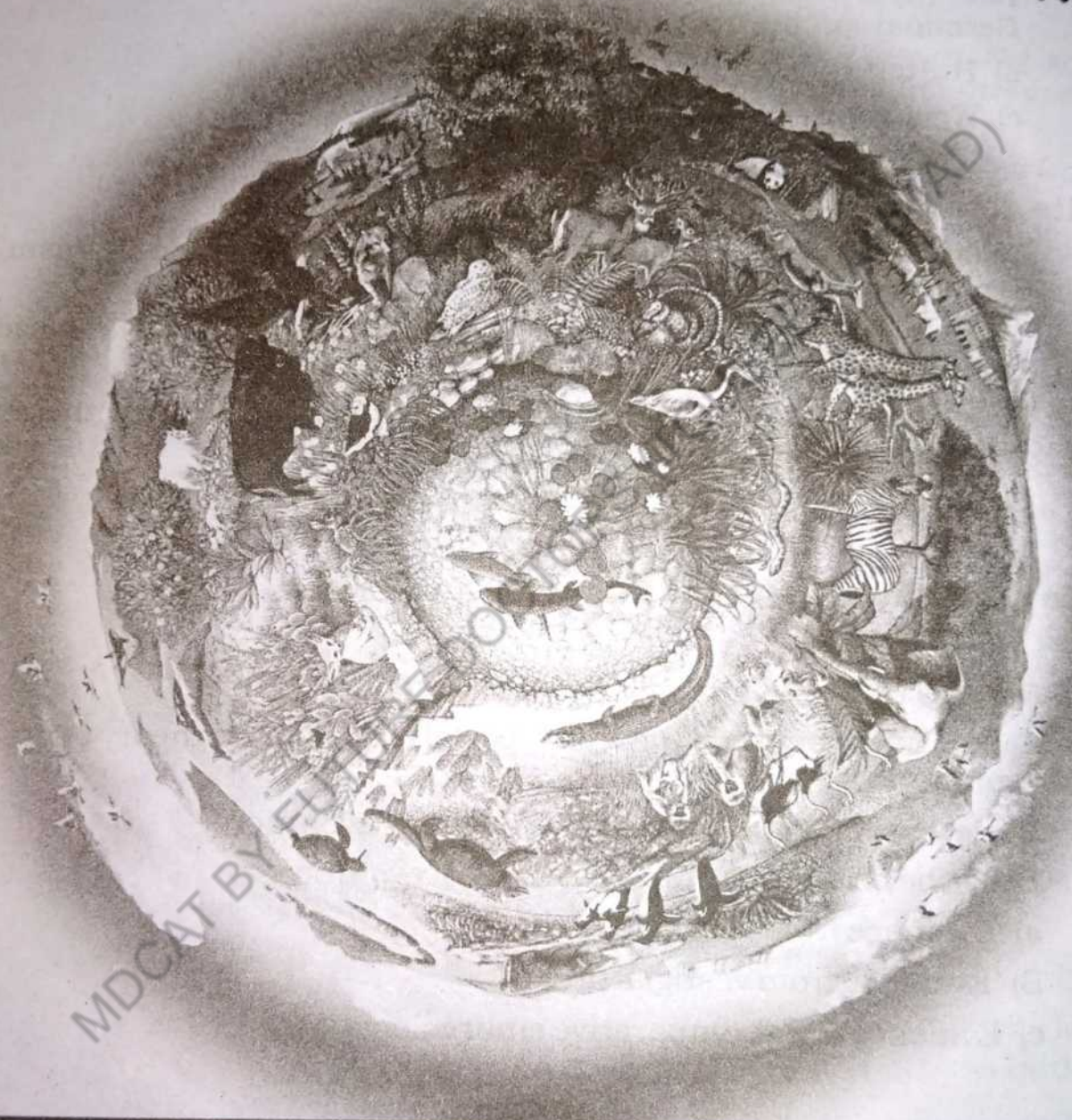
ii) Differentiate between theory of special creation and theory of organic evolution.

iii) Write a short note on Lamarck's theory of evolution.

iv) Describe briefly following evidences of evolution.
a) Evidence from Homology
B) Evidence from vestigial organs
c) Evidence from comparative embryology

SECTION-III

ENVIRONMENTAL BIOLOGY



Environmental biology is a science which deals with problems being faced by environment. Explosive growth in human population, over utilization of natural resources, industrialization, dumping of nuclear wastes and other pollutants have causes severe damage to the environment. The environmental scientists derive basic tools from ecology, meterology, geology and other sciences to solve these problems.

CHAPTER 11

ECOSYSTEM

The interaction between living things and their non living environment regulates flow of energy and cycling of nutrients through biogeo-chemical cycles. By using nutrients plant prepare food with the help of sunlight, they are eaten up by consumers of various trophic levels and ultimately communities develop by the process of succession, which are more stable units. Human activities are threatening this stability for their own growing needs.

No living organism lives seperateraly as a single unit. Each living organism is surrounded by material and forces which constitute its environment, from which it must derive its needs. For these basic requirements each living organism has to depend and interact with different non-living and living components of the environment. In this way the organisms of a particular area not only interact with physical environment, but also interact between themselves and this process remains continuous in that area.

The scientific study of various relationships of living things to each other and with their environment is called **ecology**. This term was first introduced by a German biologist **Ernest Hackel** in 1869. It has been derived from a Greek root **oikos**; means home life or living place and **logos**, means the science or study. Now a days, the ecology is usually referred as **environmental biology**.

11.1 LEVELS OF ORGANISATION

The ecological studies in contrast to others, deal with the levels beyond organisms. Thus, it begins with group of organisms and ends on ecosystem. The group of similar individuals (species) that live together in the same area at the same time, in ecological term form a **population**. A population of particular locality is always well adapted to surroundings. The second level of ecological organization is **community.** It consists of all populations living in a particular area. A community interacts with non living environment and both function together to form an **ecosystem** level of organization. The **environment** is a collective term for all conditions in which an organism lives. Thus all factors such as light, temperature, water, soil, air and other organisms constitute environment.

The type of environment in which a particular organism or population lives, is its **habitat** e.g. fresh water pond, a rocky shore or a rain forest etc. Each organism or its population plays an important role in particular habitat, its activities, requirements and effects are collectively called **ecological niche**.

The habitat is further divided into two main type i.e. **aquatic** and **terrestrial** habitat. The terrestrial or land habitat is mainly influenced by environmental condition e.g. temperature, rain fall etc. Soil composition (edaphic factor) and topography (surface texture of land) also influence the development of plants and animals of the area. Therefore, the distribution of population depends upon climatic factor as well as some geographical barriers. On the basis of these factors **biogeographical** regions have developed which have unique flora and fauna.

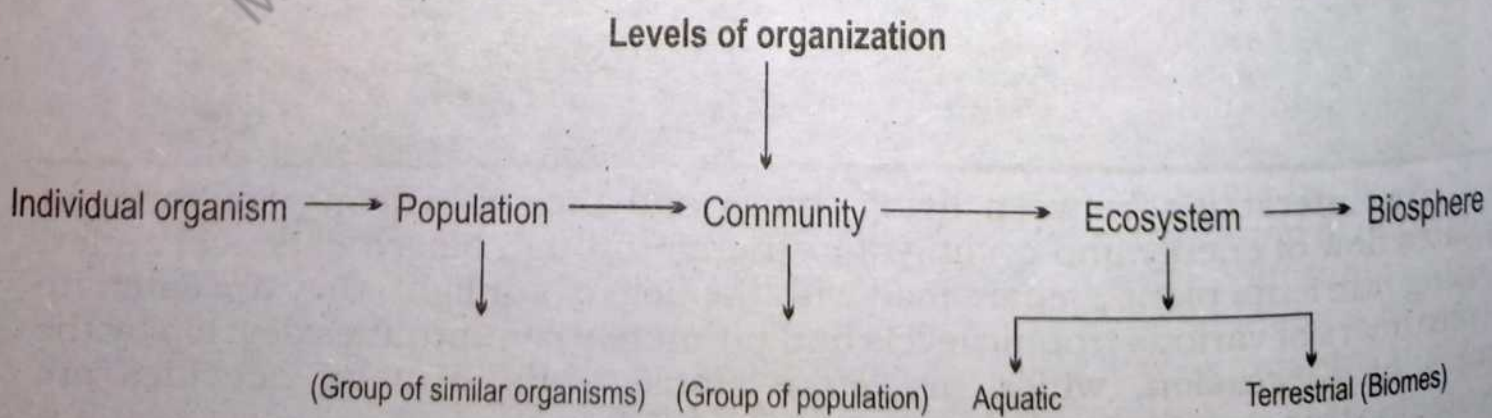


Fig: 11.1 Ecological levels of organizaion

The biogeographical regions are further differentiated on the basis of complex interaction of climate and biotic factors into large easily recognizable community units called **biomes**. The biome is recognized on the basis of dominant plant formation, such as forest or grassland and as well as environmental factors like rain forest or temperate grass land or tropical grassland (Savannah).

Biosphere:

The different ecosystems, whether terrestrial or aquatic are linked together and collectively constitute a giant ecosystem called **biosphere** or **ecosphere**. The biosphere consists of earth surface with few meters depth, water and air capsule which is of about 20 Km surrounding earth. All living things live within biosphere and no life exists beyond it.

11.2 APPROACHES TO ECOLOGY

There are several factors, which interact in a particular locality, due to this there are several approaches to undertake ecological investigations. Each approach has its own merits and demerits. Thus ecologists use one of the suitable approach to understand ecological phenomenon. These approaches are population approach or autecology, community approach or synecology, ecosystem approach, habitat approach, evolutionary and historical approach.

11.2.1 Population approach (Autecology):

This approach is based on the study of individual species, it accounts for the interrelationship between an individual species and its environment. Thus the unit of population approach is individual species. For example, if a single Mango tree in the garden is studied, the study would be **autecology** in nature or study of chemical pollution on the growth and yeild of 100 mango plant is also autecology.

11.2.2 Community approach (Synecology):

Instead of studying single or individual species the whole community and its environment is considered for ecological studies. Therefore, the study of different communities, their relation between them and their environment is called **synecology**. The term **biocoenotics** is synonymous with it. Thus biotic component of this approach includes all living things, whether they are plants or animal communities. This type of study has developed the concept of **succession** and **climax** i.e. progressive replacement of one community by more stable community and growth of it in a particular area.

11.2.3 Ecosystem approach:

This is the most recent development in ecology. Ecosystem is the highest level of biological organization, all ecological concept can be set within this framework. This approach is based on two things, the **flow of energy** and **cycling of matter** between living and non-living components. This system introduces a concept of self-regulation and self-sufficiency. Thus living organisms and their non-living environment interact in a most coordinated form and any disturbance may lead to biological disbalance. Earth is an example of ecosystem, which has both the living things (biotic factors) and non-living environment (abiotic factors)

and each influence the other. Ecosystem is a functional unit, hence it may be so small as a small pond or as large as whole world e.g. when we consider a garden community plus its soil, climate, temperature, water mineral cycle, sunlight etc, it means we are studying a garden ecosystem.

11.2.4 Habitat approach:

The organism is adapted to particular physical condition of the habitat e.g. a shallow, fast moving cold water stream may be the habitat of a species of trout. This approach is easy to define hence it is widely used. The study of physical environment like, soil, moisture, temperature and light is also convenient to study. It can be further divided into **micro habitats** or small habitats with their own special conditions.

Some ecologists divide ecology on the basis of the type of habitat where organisms live accordingly. Aquatic and terrestrial habitats are two broad sub-divisions. While Aquatic habitat may be sub-divided into marine, fresh water and estuarine habitat. The estuaries are places where rivers meet sea. On the other hand terrestrial ecology may also be divided further into forest, grassland, desert habitat etc.

11.2.5 Evolutionary approach:

This approach is linked with evolutionary trend. It tells us about changes since life evolved and may predict the future changes. However, this study also needs the use of **fossil records**. Darwin's theory of natural selection and origin of species can also discussed and studied in this part of ecology.

11.2.6 Historical approach:

It deals with changes associated with the development of tools in man's history. Thus its period starts with stone age i.e 1500 to 3000 B.C. (Neolithic period). Through this approach long term ecological planning is done and new trends can be pointed out.

11.3 THE ECOSYSTEM

Interaction between a community and its physical environment is termed as an **ecological system** or **ecosystem**. The term was first used by **Tansely** in 1935. According to him "an ecosystem is a structural and functional unit of a community, which shows relationship between flow of energy and cycling of matter in between **biotic** (living) and or **abiotic** (non-living) components". Thus world and its habitat constitute an ecological system or ecosystem, it may be so small as that of a bottle consisting of some algae and protozoans. Therefore, an ecosystem is a basic functional unit with no limits or boundaries and its biotic and abiotic components interact with each other to maintain life on earth.

11.3.1 Components of an ecosystem:

The ecosystem consists of two types of components, they are non living or abiotic and living or biotic components.

1. Abiotic components:

Abiotic components of an ecosystem include every thing except life, which

surrounds an individual and is not associated directly with the presence of other organisms.

These components are broadly of two types i.e. **material** and **energy**. The materials may be inorganic and organic substances like carbon, nitrogen, water, minerals, salts, proteins and carbohydrates etc. while energy is in the form of heat which comes from sunlight and by breakdown of chemical bonds. The materials remain in continuous cycling, they enter into a living system and after death and decay again return to soil or atmosphere. In this cycling process living organisms play an important role, hence these cycles are also called **biogeochemical cycles**. Abiotic components are controlled by abiotic factors.

Abiotic factors are further divided into three types.

a) Climatic factors
b) Topographic factors
c) Edaphic factors

a) Climatic factors:

The climate of any geographic region depends on the weather condition of that area like light, temperature, water, air etc.

i) Light:

Light is in the form of radiant energy and is essential for all green plants, photosynthetic bacteria and for all organisms, which depend upon plants. It is an important factor in the process of photosynthesis. However, only three percent of total sunlight, which falls on earth is utilized by the plants. The light affects in three ways i.e. light intensity, its duration and quality.

Light intensity: It depends upon angle of incidence, seasons, latitudes and time of the day. In plants the development of chlorophyll is dependent upon it, while intense light may destroy it. Similarly plants are further classified according to their relative requirement of light and shade into **heliophytes** and **sciophytes** respectively. The development of pigments in animals, opening and closing of stomata, permeability of cell membrane, height and surface area of plant etc., also depend upon light.

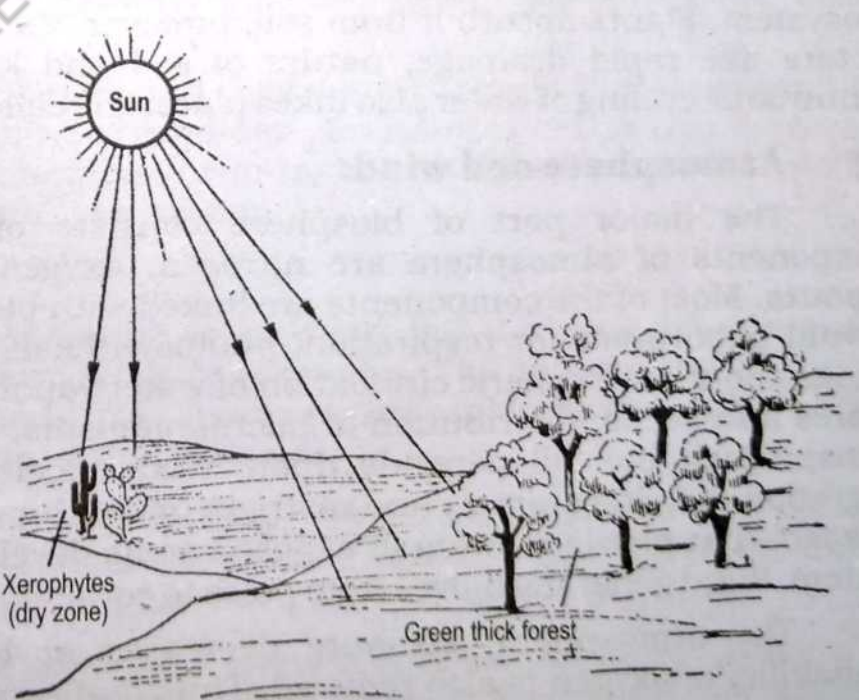


Fig: 11.2 Relation of the angle of solar rays and growth of plants

Light duration: The light duration or **photoperiod** also has marked influence on plants life e.g. flowering in plants, growth, leaf fall and dormancy etc. In animals many behavioural activities occur at regular intervals and is referred as **biological rhythms**. These rhythmic activities are regulated by photo period e.g. courtship display, nesting behaviour in spring and migration of certain groups of birds in autumn etc.

Light quality: The visible light is a small part of electromagnetic spectrum which ranges from 400 to 780 millimicron and consists of seven colours. The chlorophyll absorbs only **red** and **blue colours** to utilize in photosynthesis Ultraviolet rays of sun are absorbed or reflected back by ozone layer which form a capsule around earth, these radiations are lethal for lower organisms and also cause destruction, skin cancer and sunburn in human beings.

ii) Temperature:

The range of temperature favouring biochemical processes is narrow, its main source is radiant energy of the sun. In biosphere life mainly exists in the range of 0 to 50°C. The temperature below freezing point damages and kills the living cells and similar is the case with high temperature, where protoplasm is denatured.

iii) Water:

Water is the most important factor, because distribution of vegetation is directly related with amount of water. It is abundant in aquatic, while limiting factor in terrestrial ecosystem. It acts as solvent for various nutrients, maintain turgidity of cells, act as raw material of photosynthesis and also takes part in various metabolic reactions.

The precipitation (rain fall) is a main source of water for terrestrial ecosystem. Plants absorb it from soil, however, its availability is related to many factors like rapid drainage, nature of soil and kind of vegetation. In nature continuous cycling of water also takes place, it is called **hydrological cycle**.

iv) Atmosphere and wind:

The major part of biosphere consists of atmosphere. The gaseous components of atmosphere are nitrogen, oxygen, carbon dioxide and water vapours. Most of the components are linked with biogeochemical cycles. They are of vital importance for respiration, photosynthesis and protein synthesis. Wind brings about atmospheric circulation of water vapours and gases, the dispersal of spores and seeds, distribution of microorganisms, breaking of branches, rate of transpiration etc. all depends upon wind velocity. The wind also influences migration of flying animals and restricts timber line on high altitudes. It is due to this fact that plants growing in exposed areas develop very strong root and shoot system. Wind generally moves from poles to equator.

The atmospheric pressure decreases at high altitudes and therefore availability of oxygen is also reduced. Thus it affects the availability of animals at high altitudes. The reduced atmospheric pressure also lowers down the density of air to contain moisture, hence increases rate of transpiration. But in nature this effect is neutralized due to low temperature at high altitudes.

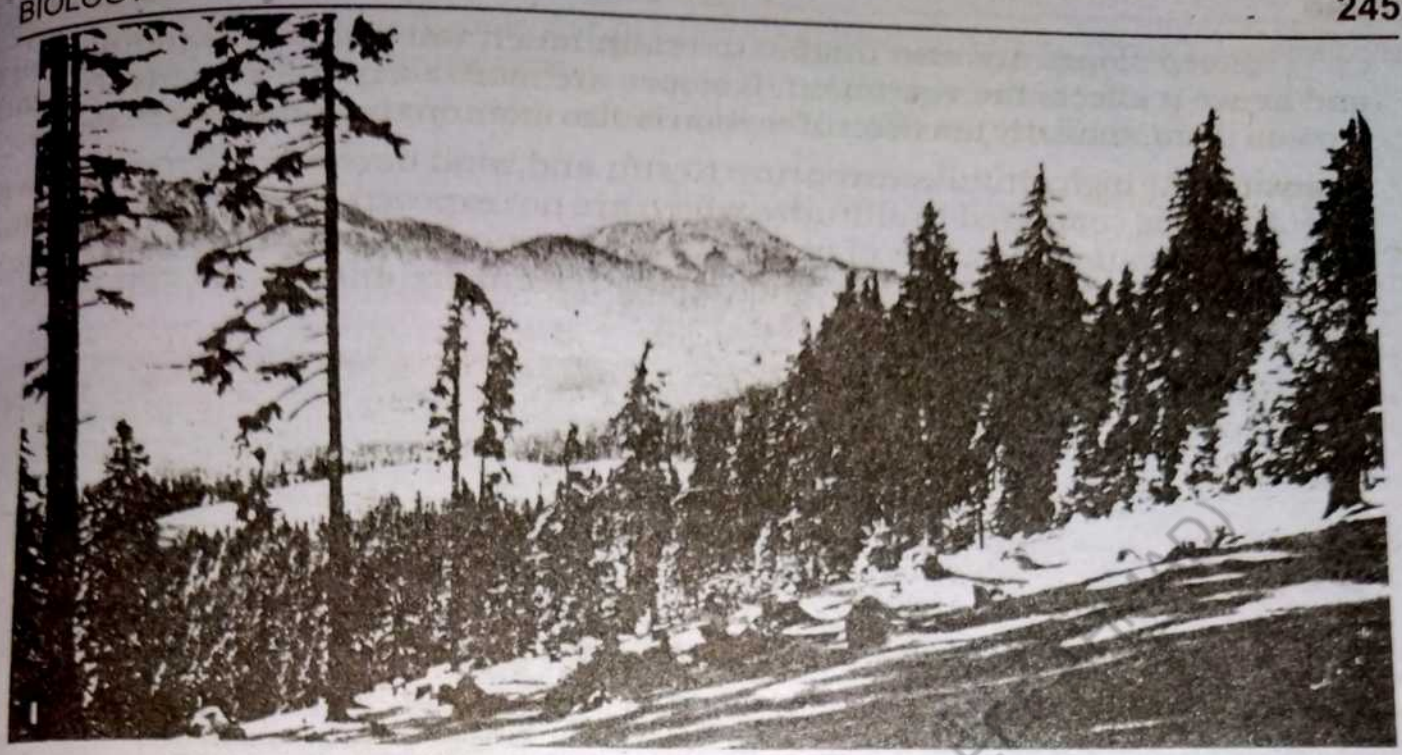


Fig: 11.3 Effect of wind velocity on plant growth

v) Fire:

The fire may be caused by lightning, volcanic activity, mutual friction between trees such as bamboos and mostly by man. The fire brings about sudden change in an ecosystem which has been developed in centuries. It recycles various nutrients and thus new growth is stimulated. Fire also brings about changes in environmental factors like light, rainfall, pH and nutrients. The fire also favours growth of some fungi, mostly ascomycetes and thus these fungi are called **pyrophilus** fungi.

Man made fires are deliberate and they are set mainly to clear ground for agriculture. It is also done to improve conditions for hunting or to promote grasses which are attractive for game animals or to make travel easier by constructing roads etc. but this destroys natural ecosystem.

b) Topographic factor:

The earth surface is not similar throughout but it shows difference, the study of surface texture is termed as **topography**. The topography has great influence on distribution of organisms. There are three main factors, which affect the topography of earth, altitude, slope and exposure.

Altitude: Higher altitudes are associated with low temperature and atmospheric pressure, higher rain, radiations and increased wind velocity, thus vegetation at different altitudes differ from one another.

Slope: The steepness of slopes affects the amount of radiation falling on them. In northern hemisphere south facing slopes receive more sunlight than north facing slopes, thus the northern slopes are cooler than south; due to temperature difference vegetation of two sides differ from one another.

Steep slopes are also unable to retain much water due to faster drainage and hence it affects the vegetation. If slopes are more steep the xerophytic plants grow on them, similarly the effect of erosion is also more on steep and barren slopes.

Exposure: At high altitudes exposure to sun and wind develops different types of vegetations as compared to altitudes which are not exposed or less exposed to sun and wind, because the angle of incidence is less and thus large amount of energy reaches to vegetation. Similarly such areas have more animals as compared to areas with less exposure.

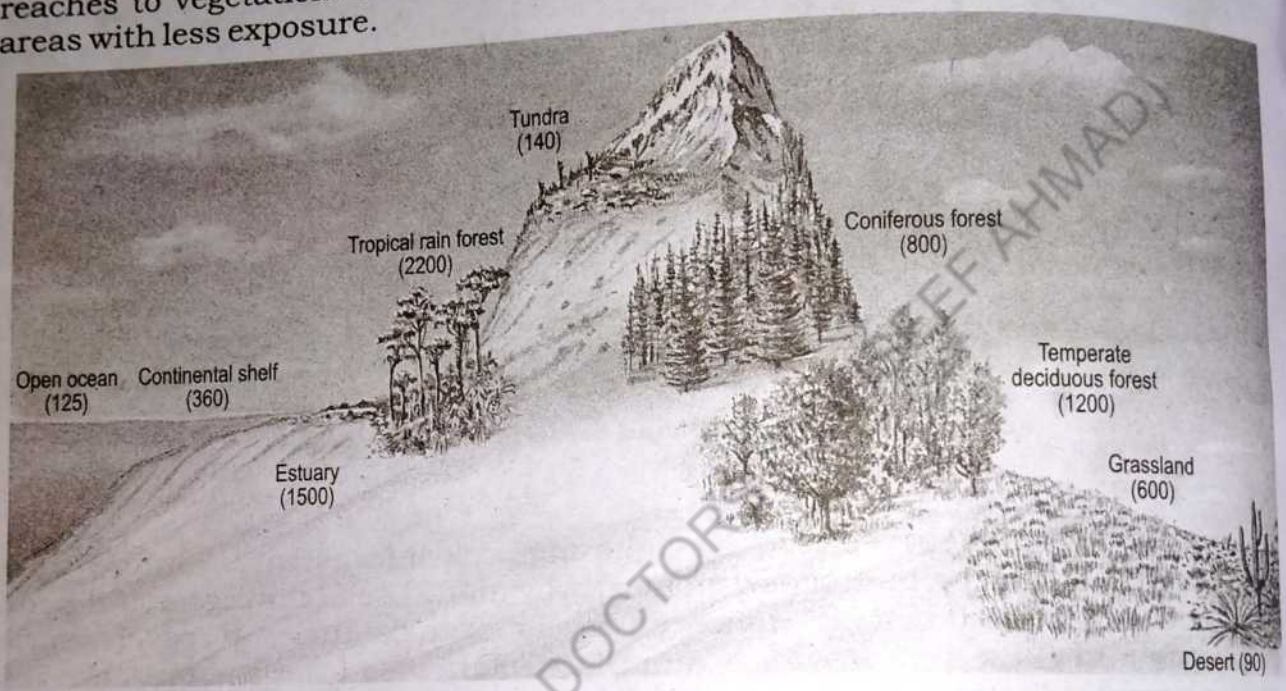


Fig: 11.4 Zonation on altitude, different types of plants grow on different altitudes

c) Edaphic factors:

Factors pertaining to conditions and composition of soil are termed as edaphic factors, while the scientific study of soil is called **pedology**; soil is a link between living and non-living components of terrestrial ecosystem. It is a layer of material overlying the rocks on earth crust. The formation of soil depends upon two processes namely **weathering** or break down of bigger rocks into fine, smaller particles and decomposition which is the breakdown of larg biomolecules into simpler molecules. The soil development is called **pedogenesis**.

2. Biotic components:

The biotic components of an ecosystem are living things, which on trophic basis (troph = nourishment) are further classified into two types i.e. autotrophs and heterotrophs. The **autotrophs** (auto = self, trophs = nourishing) are the plants and other organisms which possess chlorophyll and can prepare their own food from simple inorganic substances. However, **heterotrophs** (hetero = different, trophs = nourishing) depend for their nourishment on other organisms. Animals, fungi and most of the bacteria are heterotrophs and they derive their food directly or indirectly from the food prepared by the green plants. On the basis of production of food and its consumption, the biotic

components of an ecosystem are further classified into three types i.e. **producers, consumers** and **decomposers.**

(a) Producers:

The producers are mainly green autotrophic plants, which are present in both aquatic and terrestrial ecosystems. The sunlight is trapped by microscopic phytoplanktons (phyto = plants, plankton = floating) and other hydrophytic plants in aquatic habitat. The chlorophyll containing organisms convert carbondioxide and water into energy rich carbohydrates by a process known as **photosynthesis**. Beside carbohydrates, plants also prepare proteins and other chemical substances and for this purpose they also absorb various nutrients of abiotic components.

The autotroph may be a unicellular bacteria or a giant, 100 metres tall red wood tree.

(b) Consumers:

The consumers are heterotrophic organisms, which are mainly animals. They cannot prepare their own food and hence get prepared food in the form of plants and animals. On the modes of their feeding, consumers are further classified into **primary**, **secondary** and **tertiary consumers**.

Primary consumers: The primary consumers are **herbivores** i.e. they feed only on plants. The insects like grass-hopper and leaf-hopper, while animals such as goat, sheep, cow, rabbit, mice and deer which specifically feed on plants; belong to this class of consumers in a terrestrial ecosystem. Zooplanktons (Zoo = animals, plankton = floating) crustaceans and herbivorous fishes of an aquatic habitat also belong to this class of consumers.

Secondary consumers: They are carnivorous animals which feed upon herbivores or primary consumers, such as a frog eat grass-hopper and a **carnivorous** fish eat a herbivore fish. However, some of the secondary consumers are omnivorous i.e. they feed upon mixed diet of plants and animals.

Tertiary consumers: In most of the ecosystems, there are some predatory animals which get their food by preying other animals. These animals in turn are not eaten or killed by other animals, however, after the death, their bodies are decomposed by micro organisms. The predatory animals are eagles, tigers and lions.

(c) Decomposers:

They are microscopic **saprotrophs**, mostly fungi and bacteria. They fulfill their need of energy from protoplasm of dead plants and animals. The microbes decompose organic media and utilize some of them, while rest is released in environment and made available for consumption of producers. Therefore, the decomposers play an important role in recycling the materials.

11.4 BIOGEOCHEMICAL CYCLES

The protoplasm consists of various elements, hence regular supply of these elements is very important for an ecosystem. Therefore, these elements are constantly recirculated in the biosphere in a characteristic path from environment

to organisms and back to the environment. These circular paths are called **cycles** or **biogeocycles** of an ecosystem. Carbon, hydrogen, oxygen and nitrogen are present in almost all compounds involved in metabolic activities, hence they are essential for maintenance of life. The carbon, hydrogen and oxygen are closely related to one another and form carbon, hydrogen and oxygen cycle, while phosphorus and nitrogen form independent cycles.

11.4.1 Nitrogen cycle:

Nitrogen is indespensible in nature, it is essential for chlorophyll and amino acids which form proteins. It constitutes main bulk of atmosphere, where it is present in about 78% in ratio. The atmospheric nitrogen is inert and does not readily participate in any reaction. However, it is cycled from environment to organisms and back to environment by several paths. Nitrogen is fixed from atmosphere through different sources and is absorbed by the plants in the form of nitrates.

> Nitrogen is a major part of amino acids, DNA, RNA and ATP. Air contain 78% of nitrogen and 30 millions tons of atmospheric nitrogen is fixed artificially per year and thus it has important effect on the amount of nitrogen in the environment.

The first source of soil nitrates is decomposition of organic compounds, which take place in two steps; first the organic compounds are broken down into ammonia, this process is called **ammonification**. Later on the nitrifying bacteria like **nitrosomonas** convert ammonia into nitrites and then **nitrobacter** an other bacteria convert it into nitrates. This process is known as **nitrification** and it takes place in well aerated soil. The second source of soil nitrates are bacteria like **azotobacter**, **clostridium** and a blue green algae (Cyanobacteria) *Nostoc*. They bring about **symbiotic** nitrogen fixation. Another bacterium *Rhizobium* is present in root nodules of leguminous plants like pea and soyabean it also brings about symbiotic nitrogen fixation. The third source of nitrogen is thunderstorm and lightning during which nitrogen combines with oxygen and forms oxides, which dissolve in water and ultimately form nitrates.

The nitrates are absorbed by roots and are later on converted into amino-acids and then to proteins. The protein is later on taken up by animals and is broken down and is reconstituted as animal protein. The animals produce nitrogenous waste to which putrefying bacteria break down into ammonia compounds and then nitrite bacteria i.e. **Nitrobacter** convert it into nitrates, which is absorbed by plants and thus recycled. Similarly, the proteins present in dead bodies are also acted upon by bacteria in similar way.

Thus the constant supply of nitrogen from atmosphere to organism makes ecosystem to work properly.

Denitrification: The denitrifying bacteria are also present in soil and they reverse the process of nitrification and so reduce soil fertility. These bacteria are anaerobic and they use nitrates as oxidizing agent instead of oxygen and so some of the nitrogen is wasted. It is due to this fact that good drainage and through ploughing restrict their activity and helps in increased soil fertility.

11.5 INTERDEPENDENCE OF ORGANISMS AND THEIR SIGNIFICANCE

In an ecosystem organisms are interdependent which is generally called **interaction**. These interactions between organisms may be beneficial or harmful, thus they are divided into two types.

a) Positive interactions:

In this type of interaction organisms help one another to get food or other benefit, thus the benefit is reciprocal or it may be one way, the commensalisms and mutualism belongs to this type of interaction.

b) Negative interactions:

This type of interaction causes harm to one of the species. Thus one population may eat other or they compete for food and other resources. The parasitism, predation and grazing belong to this class.

The living organisms in an ecosystem form close association with the species of their own or with other species. The association between same species are called **intraspecific associations** while that in between different species are known as **interspecific associations**. The intraspecific associations commonly take place in social animals and lead to social organization of their communities. In interspecific associations, one organism actually provides habitat to other organism. The interspecific associations are parasitism, symbiosis, predation and grazing etc.

1. Parasitism:

It is an association in which one organism, the parasite lives temporarily or permanently within or on another organism called host. In this association parasite is benefitted, whereas the host is at loss. Thus they regulate the population of plants and animals.

Parasite which lives on the surface of the host, is called **ectoparasite**, such as fleas and leeches, whereas those living within the host are called **endoparasites**, such as *Plasmodium* and *Taenia*.

2. Symbiosis:

It is an association between two different living organisms but neither is harmed. The symbiotic associations are of two types i.e. mutualism and commensalism.

a) Mutualism: It is a relationship between two organisms for mutual benefit. The organisms may be two animals, two plants or a plant and an animal. In leguminous plants, root nodules are inhibited by nitrogen fixing bacteria. The bacteria fix atmospheric nitrogen for the plant and in turn gets shelter, so both partners are benefited. Similarly a lichen is the result of association between green alga and a fungus. The sea anemone and hermit crab provide another example of mutualism, the crab is protected by sea anemone and the sea anemone gets free ride and a variety of food.

b) Commensalism: In this relationship one organism, the commensal gets benefit from host, but host does not get benefit nor it is harmed. The epiphytic plants grow on trunks of other plants, but they get only support, however obtain their food and water from atmosphere. They are common in tropical rain forest. The Orchids and

Mosses are common epiphytes. Some small fishes live within the cloaca of sea cucumber for protection but do not harm sea cucumber.

3. Predation:

Predators are those animals, which take their food by preying upon other living animals. The predators may be secondary or tertiary consumers of an ecosystem. The prey-predator relationship is an important factor which influences population size. Some times the number of individuals eaten up is so small that it makes no difference. It actually depends upon the population of predators, the ospreys (hawks) live on fishes of ocean and their supply is so enormous that it cause no harmful effect upon the preys. However, if supply of prey is less as compare to population of predators then predators may become extinct. Thus, there are numbers of prey and predator cycles, such as lions and zebras.

4. Grazing:

The herbivores in an ecosystem feed upon green parts of plant. They include both small and large animals like rabbits, sheeps, cattles, horses, zebras and elephants. The extensive loss of leaves lead to starvation of food due to fact that rhizome and roots are not properly developed. The aerial parts of plants also prevent grazing by receding themselves, however, grasses are more tolerant to this effect than other plants.

11.6 ECOLOGICAL SUCCESSION

The change in environment is a continuous process and it plays an important role in development of communities. Due to environmental changes over a period of time, it is difficult for a community to maintain itself; hence new communities may develop and even if the climate is stable for longer period i.e. years after years the ecosystem has ability to change simpler forms into more complex forms and thus a community may change. This process of orderly community change is called **succession**. The succession results in increase in total number of species in particular area and a stable community is developed for a certain period of time, this stable collection of plants and animals is referred as **climax community**.

Hult (1885) first time used the term succession for orderly changes in community. The two main types of succession are primary and secondary successions.

> Succession continuously changes the kinds of plants and animals.

1. Primary succession:

The areas never having living things before, like newly deposited lava, newly formed sand dunes or areas developed due to land slides , erosion, it may be marine, fresh water or terrestrial in such basic environments the development of life activity leading to community is called primary succession. The initially establishing plants in such areas are referred as **pioneers** or primary community.

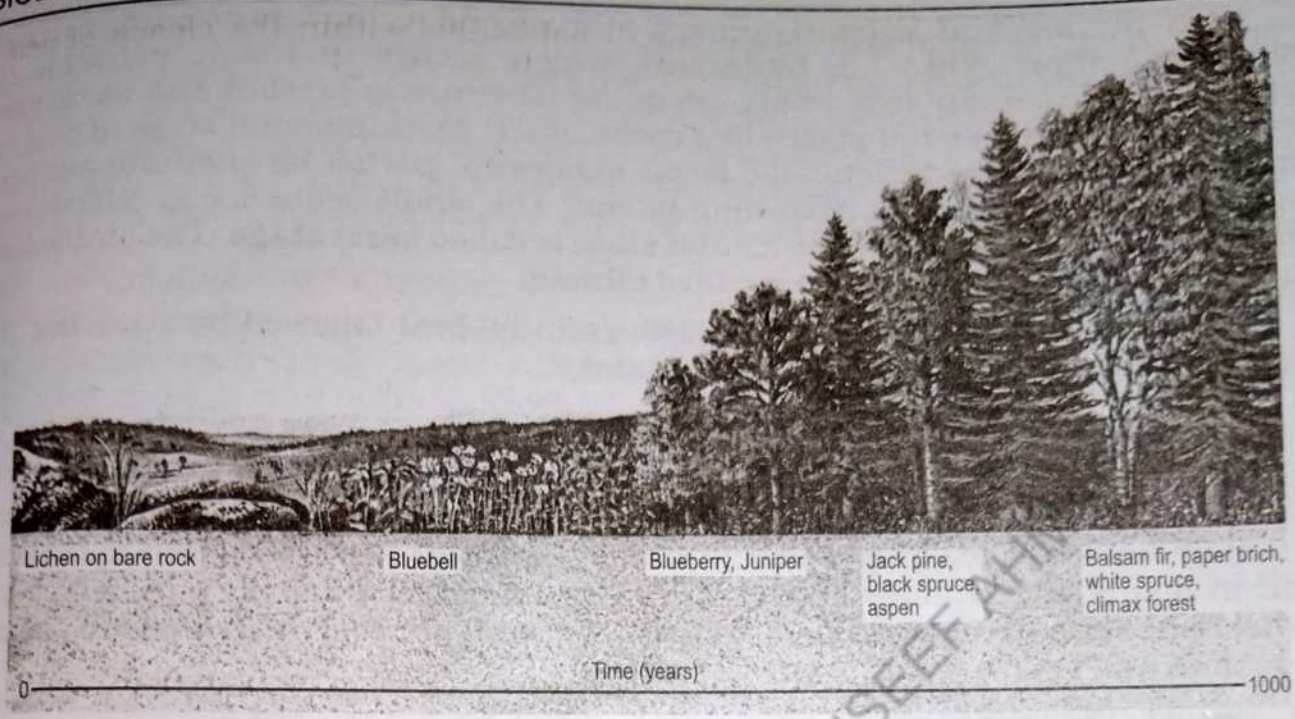


Fig: 11.5 Primary succession is shown occurring on bare rock

2. Secondary succession:

This type of succession occurs on places which were previously occupied by living things, but were destroyed by fire or any other climatic or biotic change. Due to such changes, area looks to be bare, but its substratum is built up though devoid of living matter. Due to built up substratum , the succession is more rapid and climax communities are developed; which are different from previous communities.

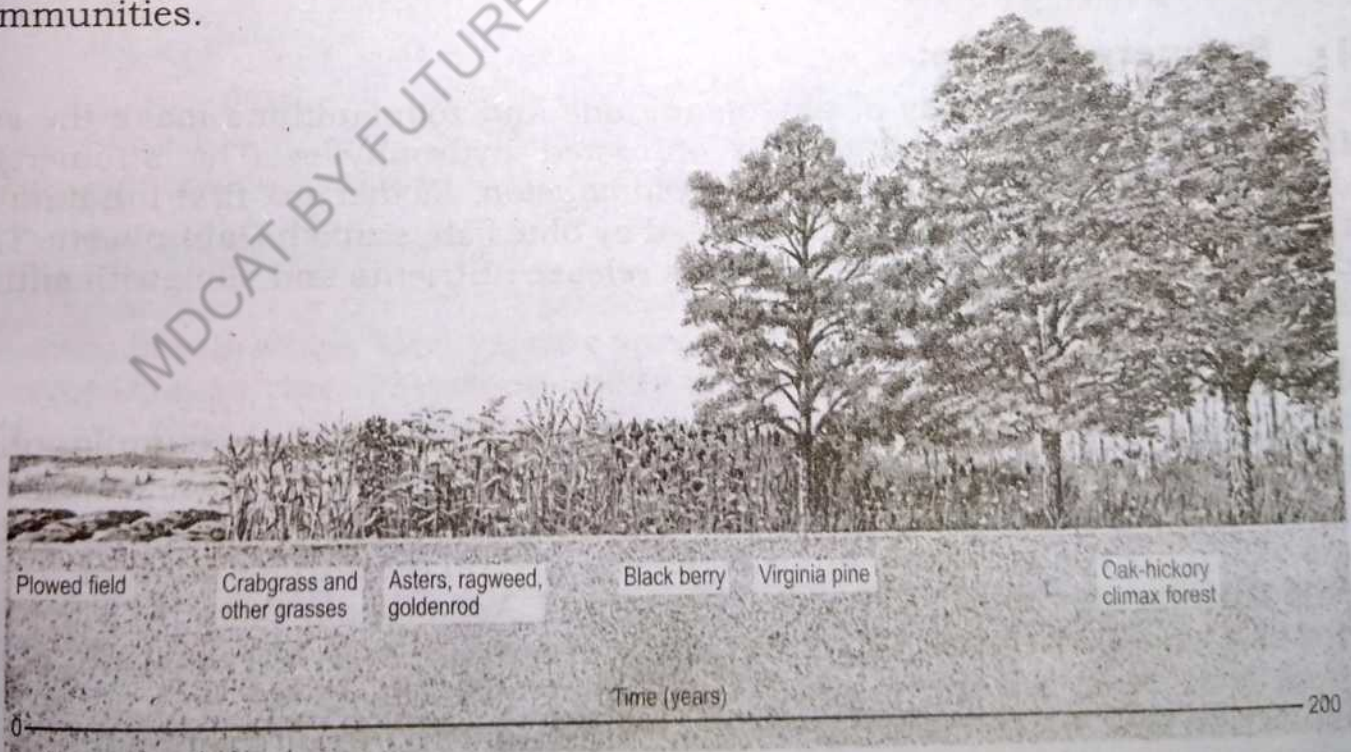


Fig: 11.6 Secondary succession is shown occurring on a plowed field

On the basis of habitat primary and secondary succession are further divided into three types i.e. **hydrosere** which occurs in water, mesarch or **mesosere** occurs in an area where adequate moisture is present and **xerosere**, occuring on dry terrestrial places like rocks. Each developmental stage of climax community have characteristic life forms alongwith particular environment and stages are continuous from beginning to end. The whole sequence is referred as **sere**, while the individual developmental stage is called **seral stage**. The stable and a mature community of a climate is called **climax.**

The process of ecological succession can be best followed by studying the following type of succession in aquatic habitat.

1. Hydrosere or Hydrach:

Primary succession in open water like ponds, pools or lakes which are ultimately converted to land community constitute hydrosere. Succession actually occur in plants and animals both, however much visible changes can be seen in plants; hence it looks succession of plants. The seral stage of hydrosere in a pond are as follows.

(i) Phytoplankton stage:

Algal spores may be brought by wind, alongwith soil particles and deposited on water. The unicellular and colonial planktonic forms are the first invaders and hence this stage is called phytoplankton stage.

The phytoplanktons are the pioneer species and so they form pioneer community. They include blue green algae *(Cyanobacteria)*, green algae *(Spirogyra, Oedogonium)*, diatoms and bacteria, they first colonize a pond and reproduce to increase their number . The protozoan like *Amoeba, Paramecium* and *Euglena* are the pioneer species of a pond.

(ii) Submerged stage:

The death and decay of phytoplanktons and zooplanktons make the soil suitable and softer for the growth of rooted hydrophytes. The submerged hydrophytes like *Hydrilla, Vallisnaria, Potamageton, Elodea* etc. first inhabitat a pond. The animal life is mainly represented by blue fish, sunfish Daphnia etc. The hydrophytes die and decompose and thus release nutrients and alongwith silting also reduce the depth of water.

(iii) Floating stage:

The death and decay of submerged hydrophytes with the accumulation of sediments washed into the pond from the surrounding area decrease water level upto few feet. Therefore pond become suitable for development of another type of plants which are rooted in soil, but their leaves float on the surface of water. These species include *Nymphea, Eichornia, Trapa* and *Nelumbium*. Some free floating plants can also be seen at this stage, they include, *Azolla, Lemma, Pistia* and *Salvinia* etc. Most of these plants accelerate the losses of water through transpiration due to which water level is very much reduced. The animal life is mainly represented by *Hydra*, snails, frog, diving beetles etc.

(iv) Reed swamp stage:

This stage is also referred as amphibious stage. At this stage most of the species though rooted in soil but have most of their parts above water table. Due to fact that the death and decay of plants make pond more shallow. The plants have well developed rhizomes and form a thick vegetation. The representative plants of this stage are *Typha*, *Polygonum*, *Phragmites* and *Sagittaria* etc. while animals like lymnea, physae, insects like water scorpion and giant bug are present.

(v) Sedge meadow stage:

The continuous decrease in water table and favourable changes in substratum makes the pond suitable for plants, they have much branched rhizome system. The dense growth of plants increases the rate of transpiration, which ultimately exposes the marshy soil. The nutrients present in pond due to action of oxygen of air are now oxidized to nitrates and sulphates. The representative plant species of this stage are *Juneus*, *Cyperus* and *Carex*. The animals of this stage are snails like *Anodonta* and *Psidium*.

(vi) Wood land stage:

The soil at this stage becomes more and more drier. Thus the marshy vegetation disappears and area becomes rich by terrestrial plants like *Salix* (shrub) and *Populs* (tree). The animals at this stage are of terrestrial habitat like Zebras, Deer etc.

(vii) Climax stage:

The wood land community is finally invaded by trees. The development of climax community is dependant upon environment. If there is heavy rainfall then tropical rain forest is developed, but if there is moderate rainfall as in temperate regions then the mixed forest is developed.

2. Xerosere:

It occurs on a bare rock or land, where there is lack of water and organic matter, though having some minerals. These stages are designated on the basis of dominant plant types, which are as follows.

(i) Crustose lichen stage:

A bare rock or land do not possess moisture and organic matter, but lichens are such plants which form pioneer species in this area, they can also survive in extreme temperature. They have ability to produce acids, helpful for weathering rocks and thus produce better substratum for other species. The lichens of this stage are *Rhizo- carpon*, *Rinodine*, *Lecanora* etc.

(ii) Foliose and fructiose lichen stage:

Lichens of this stage have large leafy structures they have ability to absorb moisture and retain it. They also hold up soil particles and make substratum more rich. Ultimately a layer of soil is developed on the rock surface. Examples of these lichens are *Pasmelia*, *Dermatocarpon* etc. Animals of early lichen stages are mites, ants and spiders present in cracks.

(iii) Moss stage:

The thin soil layer favours the growth of mosses, which requires little water. Due to further death and decay of lichens, soil becomes more rich in nutrients. The plant species of this stage are *Polytrichum*, *Grimmia*, *Selaginella* etc. Animals like mites and spiders increase their number at this stage.

(iv) Herbs stage:

Early stage is characterize by the development of annual herbs and later on perennial herbs. Due to enough accumulation of soil, the xeric conditions are also changed and shallow rooted grasses are developed, such as *Aristida*, *Poa* etc. This stage also favours the animals like nematodes, larval insects, mites, ants etc.

(v) Shrub stage:

At this stage habitat becomes more suitable for the growth of shrubs. The soil becomes rich with moisture and minerals. The shrubs over shadow the grasses, favourable plants, which migrate to this area are *Rhus* and *Phytocarpus*. During shrub stage large number of fauna is also developed such as slugs, snails, millipedes centipedes. Salamanders and frogs (amphibians) reptiles, birds and mammals like shrew, squirrels and foxes etc.

(Vi) Climax stage:

The accumulation of soil and humus favours the growth of some xerophytic trees, which further convert climate to mesophytic form and thus the final population is developed, which vary from place to place and is called climax community.

A small community changes more quickly than a large community. A small community may contain one or two species and if they die than whole community is perished.

KEY POINTS

- The study of relationships of living things to each other and with their environment is called ecology.
- The similar individuals in ecological term form a population.
- All species living in a particular area constitute community.
- The interaction between a community and its physical environment is termed as ecosystem.
- The earth alongwith its air capsule constitute biosphere.
- Plants growing in shade are called sciophytes.
- In biosphere life exists in range of 0°C to 50°C.
- Nitrogen in atmosphere is about 78% by volume.
- Ozone is about 0.000004% by volume in air.
- The scientific study of soil is known as pedology.

EXERCISE

1. Encircle the most correct choice:

i) The study of living things in relation to its environment is called.

a) Community b) Ecosystem
c) Ecology d) Succession

ii) The concentration of oxygen in atmosphere is about.

a) 21% b) 50%
c) 30% d) 60%

iii) The ideal soil for plant growth is

a) sandy soil b) clay soil
c) loam d) silt.

iv) The decomposers of an ecosystem are

a) Parasite bacteria b) Fungi
c) Bacteria d) Bacteria and fungi

v) The relationship of Hydrictinia and Hermit Crab is called

a) Mutualism b) Commensalism
c) Parasitism d) Predation

vi) The term succession was first time used by Hult in year

a) 1971 b) 1900
c) 1885 d) 1965

vii) Similar group of individuals who can interbreed and produce organisms of their own kind form a:

a) Population b) Community
c) Species d) Succession

viii) The living organism which can prepare their food for themselves and other living organism.

a) Predators b) Parasites
c) Producers d) Prey

ix) The relationship between members of two diferent species in which both get benefit:

a) Parasitism b) Mutualism
c) Symbiosis d) Commensalism

x) The producer of a pond-ecosystem is:

a) Bacteria b) Zooplankton

c) Phytoplankton d) Fungi

2. Write detailed answers of the following questions:

i) Write a detailed note on different approaches used for ecological investigations.

ii) Write a note on different abiotic components of an ecosystem.

iii) What is ecosystem, write a note on biotic components of an ecosystem.

iv) What are biogeo-chemical cycles? Describe in detail the nitrogen cycle.

v) What is ecological succession? Also describe Hydrosere.

vi) Describe in detail the xerosere.

3. Write short answers of the following questions :

i) Describe briefly various ecological levels of organisation.

ii) Write a short note on Habitat approach.

iii) Write a short note on light as a climatic factor.

iv) How edaphic factors effect an ecosystem?

v) Explain briefly the positive and negative interactions.

vi) Describe briefly two main types of succession.

vii) Write a short note on symbiosis.

viii) What is denitrification?

ix) Whey distribution of population depends upon climantic factors?

x) Whey water is most important factor of eco system?

4. Define the following terms :

i) Population ii) Community

iii) Environment iv) Habitat

v) Ecological niche vi) Parasitism

vii) Hydrosere viii) Xerosere

ix) Topography x) Synecology

CHAPTER 12

SOME MAJOR ECOSYSTEMS

Ecosystem is a distinct functional unit in which regulated flow of energy and cycling of nutrients take place. The ecosystem are of two major types aquatic and terrestrial. The aquatic habitat is again of three types, the fresh water habitat marine habitat and estuarine habitat. However terrestrial ecosystems are recognized as biomes, which are tundra, coniferous forest, temperate deciduous forest, desert, grass land, savannah and tropical rain forest.

An ecosystem is a basic functional unit in ecological studies, which is composed of living organisms interacting with each other and with the abiotic environment in a given area. The term **ecosystem** may be applied to communities and habitats over a wide range of size. Thus an ecosystem may be as small as dead trunk tree, a puddle, a pond, or as large as an ocean, desert or forest.

All ecosystems whether a pond, sea, forest, grassland, desert or tundra etc., have more or less similar fundamental plan of their gross structure and function. However, they differ in their communities and rate of production etc. Following is the general account of some important types of ecosystems.

12.1 LIFE IN FRESH WATER

The fresh water habitat occupies small area of earth but its flora and fauna are very large. It can be further divided into two types, i.e. standing water or *lentic*, such as ponds, lakes and swamps while examples of running water or *lotic* are river, springs and streams. The lentic water further be divided in the profundal zone (totally submerged plants), limnetic (partly submerged) and litoral zone (emergent plants).

Pond ecosystem:

A pond exhibits an example of fresh water ecosystem. The pond water is stationary (lentic), but it enters from surrounding ground and streams. The pond may be very small or large. It may develop behind a dam or near a river and its life span ranges from few weeks to several hundred years. The two basic components of pond ecosystem are; Abiotic components and Biotic components.

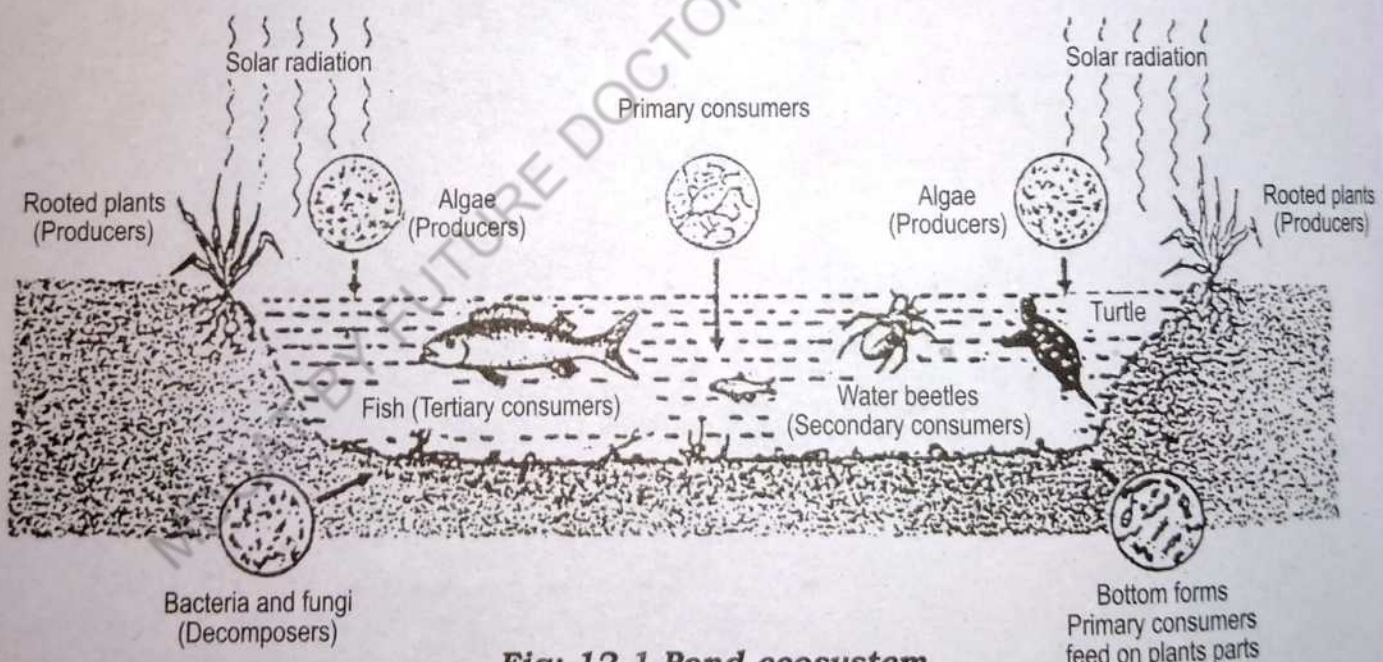


Fig: 12.1 Pond ecosystem

1. Abiotic components:

The primary productivity of pond ecosystem depends upon various nutrients. The nutrients play a major role in building up protoplasm. They include macro nutrients like carbon, hydrogen, oxygen, potassium, magnesium and sulphur. They are necessary for the operation of ecosystem, while micro nutrients, such as iron, manganese, copper, zinc etc. are required to build protoplasm. The

pond is a balanced system of water and nutrients. The nutrients are mostly in solid state and they enter in a pond from surrounding ground or streams. The nutrients are most important because they regulate the rate of functioning of entire ecosystem.

2. Biotic components:

a) Producers: The standing water of pond favours particular type of plant growth. The lower plants (microphytes) and higher plants (macrophytes) both are present in a pond. The **microphytes** or **phytoplankton** generally consists of free floating algae, like *Chlamydomonas*, *Spirogyra*, *Nostoc* and *Diatoms*. They are distributed throughout the pond as deep as light penetrates. **Macrophytes** are rooted or large floating plants which grow in shallow water. They include both types of hydrophytes i.e. totally submerged such as *Hydrilla*, *Potamageton*, *Vallisnaria*, *Trapa* and partially submerged like Water lily, *Nelumbium* (lotus) *Eichornia* (water hyacinth) etc.

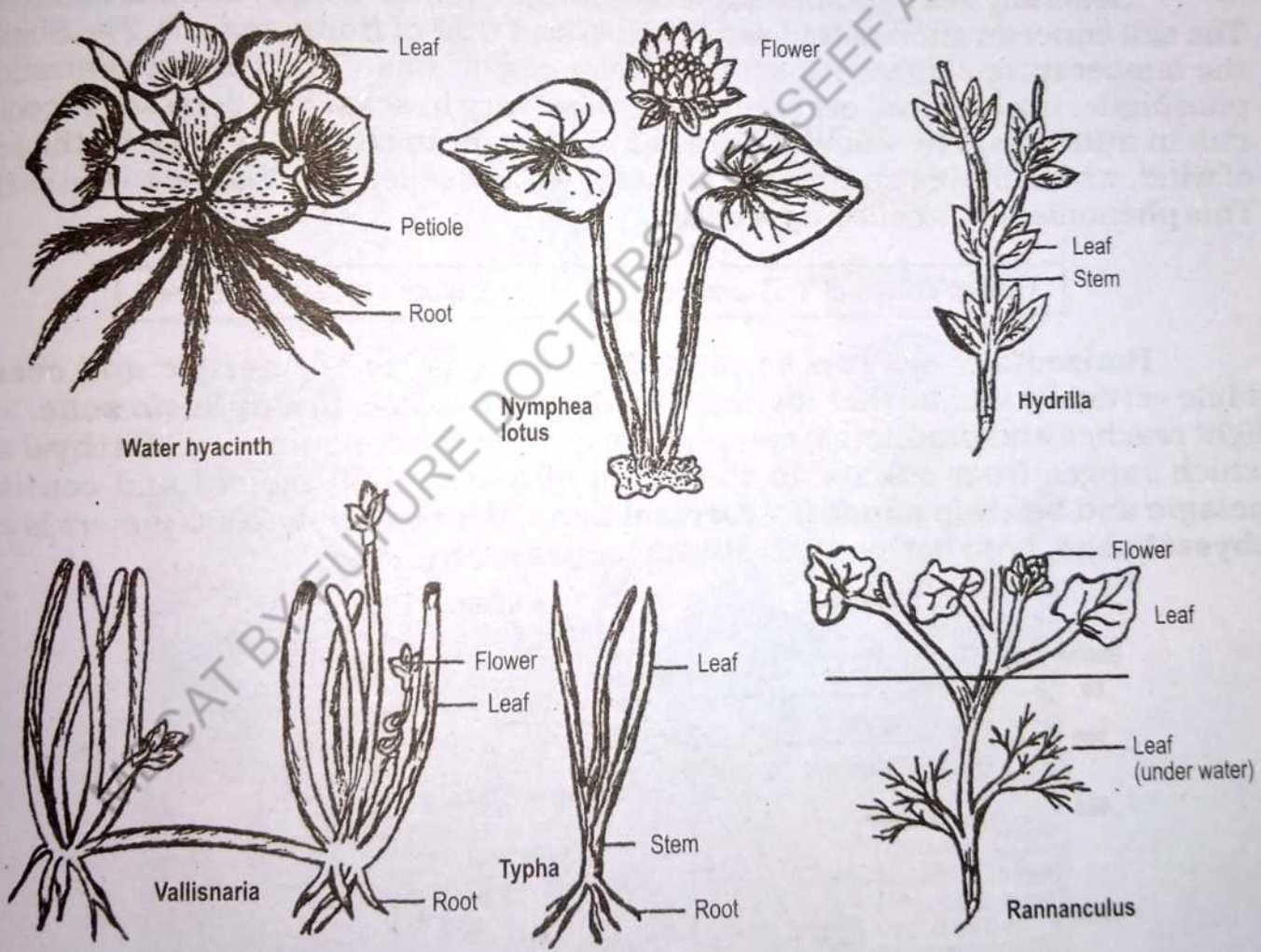


Fig: 12.2 Hydrophytic plants of a pond ecosystem

b) Consumers: The **primary consumers** are herbivores, which include crustaceans, molluscs and other zooplanktons. The herbivore fishes and some young insects also belong to this class. The **secondary consumers** feed on primary consumers. The diving beetle and carnivore fishes etc. belong to this class. The

secondary consumers are carnivores. While **tertiary consumers** are also carnivores and they feed upon secondary consumers eg: turtle.

c) Decomposers: The decomposers of pond ecosystem are saprotrophic bacteria and fungi, they are also known as micro consumers, because they absorb very small nourishment from decomposed organic matter. They bring about decomposition of dead organic matter of plants and animals origin. Fungi includes *Aspergillus, Penicillium, Rhizopus* etc.

12.2 LIFE IN MARINE WATER

The ocean is the greatest reservoir of living organisms alongwith nutrients. It covers about 70 percent of earth surface. The seas are continuous, however, factors like, salinity, temperature and also depth restrict animals and plants in particular areas.

Generally sea contains 3.5 % salt, while average temperature is about 32°C. The salt concentration of Red sea is 4.6 % and that of Baltic sea is 1.2%. Similarly the temperature also varies such as polar region has -2°C. The concentration of phosphate, nitrates and other nutrients also vary in seas. The deep sea is cool and rich in nutrients. The water of deep sea is brought to coastal surface by the action of wind, which moves surface water away, while deeper water come to the surface. This phenomenon is called **up welling**.

Ocean contains 3.5% salt and thus it constitute salt water biome.

Horizontally sea can be divided into two parts i.e. **neritic** and **oceanic**, while vertically it is further divided into three zones, i.e. (i) **Euphotic zone**, where light reaches and producers, can prepare food for the consumers (ii) **Bathyal zone**, which ranges from surface to the depth of about 2000 meters and consists of **pelagic** and **benthic zones** (iii) **Abyssal zone**, the sea below 2000 meters is called **abyssal zone**, both bathyal and abyssal zones are aphotic.

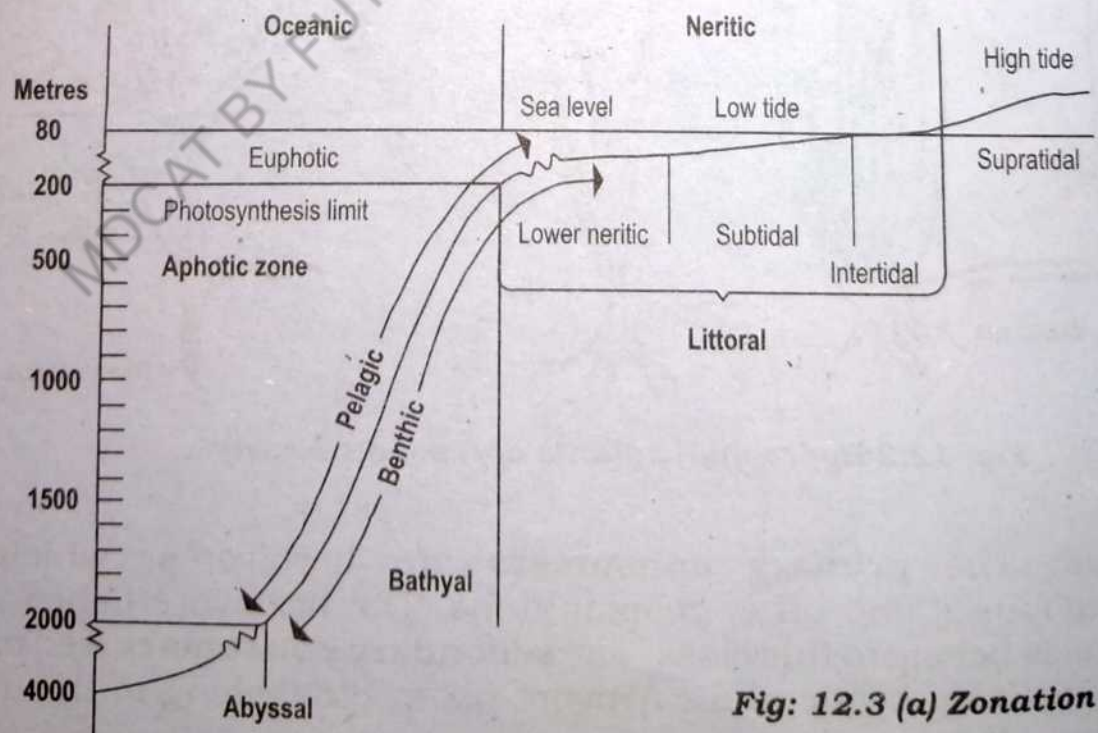


Fig: 12.3 (a) Zonation in the sea

Neritic region: It consists of shallow water, present at the edge of continental shelf. Its depth may be upto 180 meters in clear water. It is further divided into high tidal (supratidal), low tidal (sub tidal) and intermediate or inter tidal zones. The inter tidal lies in between high and low tidal zones. The ocean floor at this level is covered with water when there is high tide and is exposed when there is low tide. This phenomenon occur twice in 24 hours, it is due to movement of earth.

The neritic zone is most productive zone of the sea, it gets enough sunlight and contains oxygen, carbondioxide and other nutrients, which are helpful for luxuriant plant growth. The producers are mainly **phytoplanktons**, **diatoms** and other algae like, *Caulerpa*, *Ectocarpus*, *Cladophora*, *Dictyota* and *Laminaria*. The

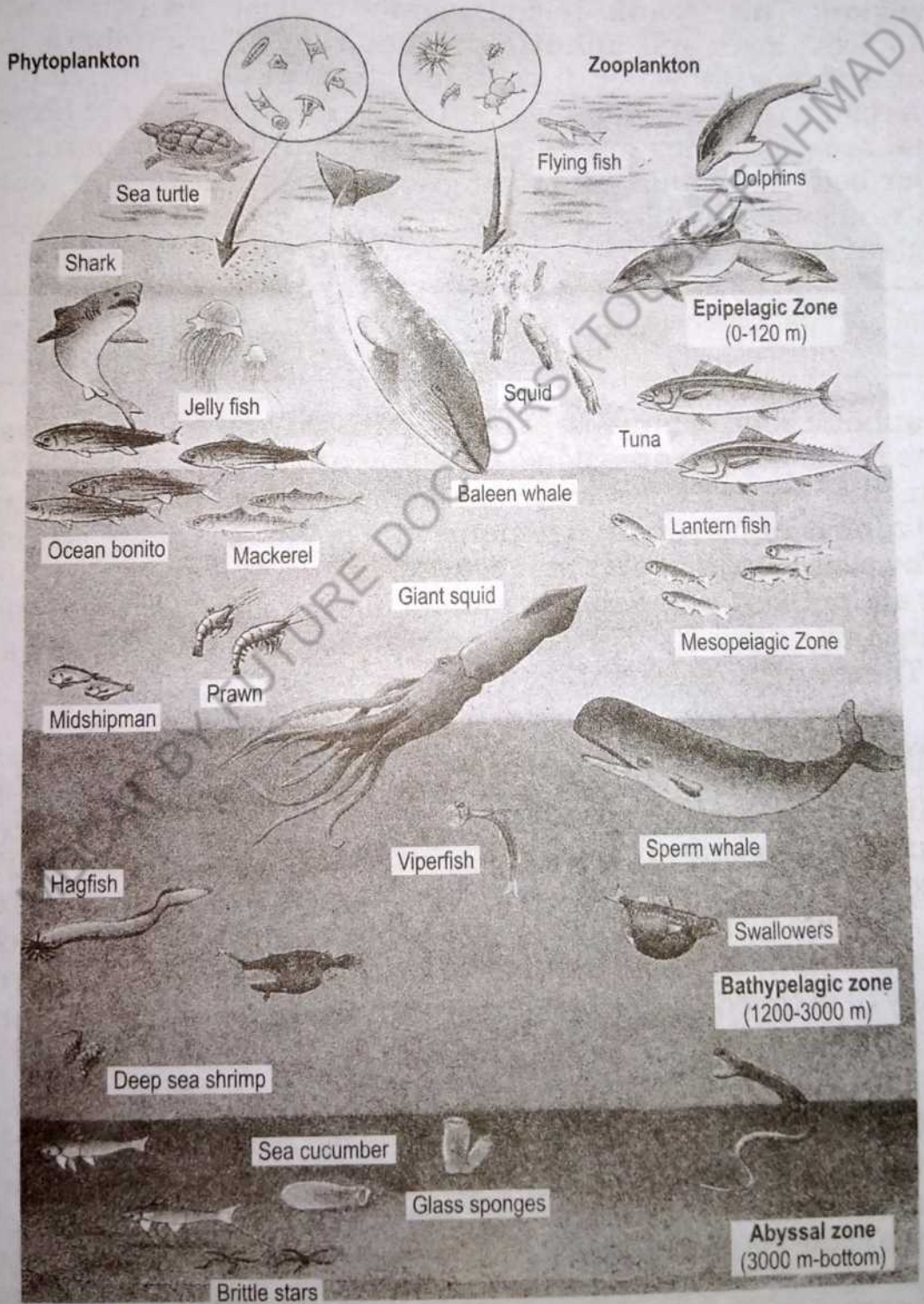


Fig: 12.3 (b) Zones in ocean

Plants of intertidal zone possess a jelly like substance called **agar**, which absorbs large quantity of water to avoid desiccation during low tides. Animals of this region also develop adaptations against desiccation. They possess shells such as snails, whereas others are of burrowing type such as shrimps, clams, bristle worm, bug worms etc. The plants of sub tidal zone are mainly phytoplanktons and diatoms, while animals are molluscs, star fish, sea cucumbers, zooplanktons, various species of fishes, crustaceans, turtles, seals and whales. Actually all animal phyla except amphibian, centipedes, millipedes, insects and Onychophora are found in sea.

Onychophora is a new phyla, it interlink between Annelida and Arthropoda.

Oceanic region: The oceanic region mainly consists of two major zones i.e. **euphotic** or light zone and **aphotic** or dark zone. The euphotic zone is more transparent than coastal water. It contains large number of phytoplanktons in a unit area, as compared to shallow water. In this zone species are lesser in number than coastal area, but they are different. They may be transparent or bluish in colour. Their bodies are smooth and shiny, such as baleen and toothed whales. The baleen whales live on phytoplanktons, whereas the toothed whale feed upon fishes and giant squids.

Physical factors dominate life in the ocean, waves, tides, current, salinities, temperature, pressure and light determines the biological communities.

The aphotic zone comprises of upper **bathyal** and lower **abyssal zones**. The bathyal zone is the continental slope, reaching upto 2000 meters. The animals in this zone are filter feeders. They sieve out food particles before reaching to bottom. The abyssal zone is rich in organic remains and shells. Plant life is totally absent in this area, However, decomposers and scavengers i.e. the animals which feed upon dead bodies are present. The fishes are small in size. They possess enlarged mouth for swallowing large animals. They also possess luminescent organs and use them for preying. Their eyes may be enlarged or absent.

12.3 TERRESTRIAL ECOSYSTEM (Biomes)

The life originated in sea and then during late Devonian and lower Carboniferous periods due to lowering of sea level land emerged. The life forms were forced to seek new habitats. This process lead to evolution of terrestrial plants and animals. The life forms on land had to face various problems such as gaseous exchange, dessication, increased effect of gravity and mode of reproduction etc. Therefore, they developed supporting tissues, skeletons, stomata, lungs, modified locomotary and reproductive organs.

The biogeographical regions are differentiated on the basis of complete interaction of climate and biotic factors into large easily recognizable unit called **biome** (Fig: 12.5), which are: forest, grassland, desertland and tundra.

The average thickness of earth is 12756 Km and only a thin layer on the surface support life. Living things can live in biosphere only or particularly those part of the earth which can supply water, oxygen and nutrients.

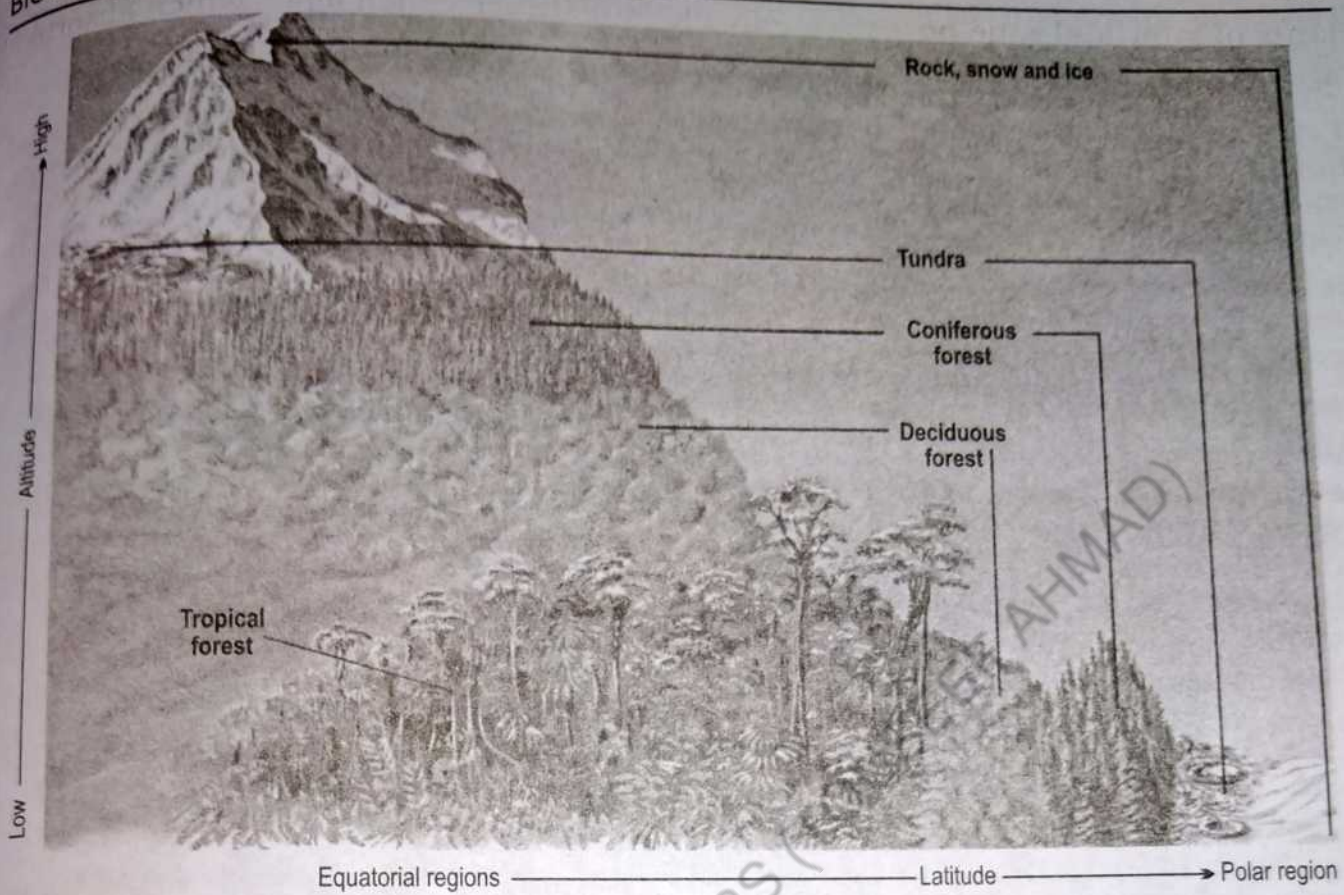


Fig: 12.4 Correspondence of vertical and horizontal biomes from mountain top to sea level and from the pole towards the equator

12.3.1 Forest ecosystem:

Forest occupies roughly 35-40% of the land surface of the earth. In Pakistan the forest occupy about 6% of the total land area. The forest of the world have been classified into three kinds as coniferous, temperate and tropical forest. Coniferous forests are confined to Northern Hemisphere where summer is short and winter is long and very cold. The temperate forest found in USA, Western Europe and East Asia, have mild temperature and moderate rain fall. The tropical rain forest grows in equatorial region where humidity is high, rainfall is heavy and annual average temperature is about 28°C. The fauna and flora of different kinds of forest varies from each other. Among all, the tropical rain forests are most rich in species composition.

1. Tropical rain forest:

Abiotic substances: High quantity of inorganic and organic substances are present in soil and atmosphere. Dead organic debri of leaves and twigs of the flora which undergo a rapid decompostion.

Producers: Flora is highly diversified. The forest is three storeyed. The upper canopy consists of very tall trees of about 40 meters in height, this canopy is dense and allows less amount of light to pass through it. The intermediate storey consists of trees having 30 meters height. While lower storey consists of small trees do not

exceeding 20 meter in height. Due to less light forest floor is covered by hygrophytes such as ferns. The epiphytes like orchids grow on to the branches of other trees. The flowers and fruits are abundant and these forests are the great source of timber.

Primary consumers: Herbivores feeding on plants include ants, beetles, leaf hoppers, bugs, spiders, monkeys, shrews, bats, mongoose, etc. About 85% of living species of birds in world are found in these forest. Majority of them feed on seeds, fruits and nectar of plants.

Secondary consumers: Most of the animals of these forest are arboreal i.e. they live on trees and they are found at various level. Snakes, predatory birds, frogs are secondary consumers.

Tertiary consumers: Top carnivores like tigers etc are not common. Snacks and predators birds are the tertiary consumers.

Decomposers: The microorganism fauna of a forest soil is very rich. This includes a wide variety of bacteria and fungi. Rate of decomposition in tropical forest is much more rapid than in any other type of soil.

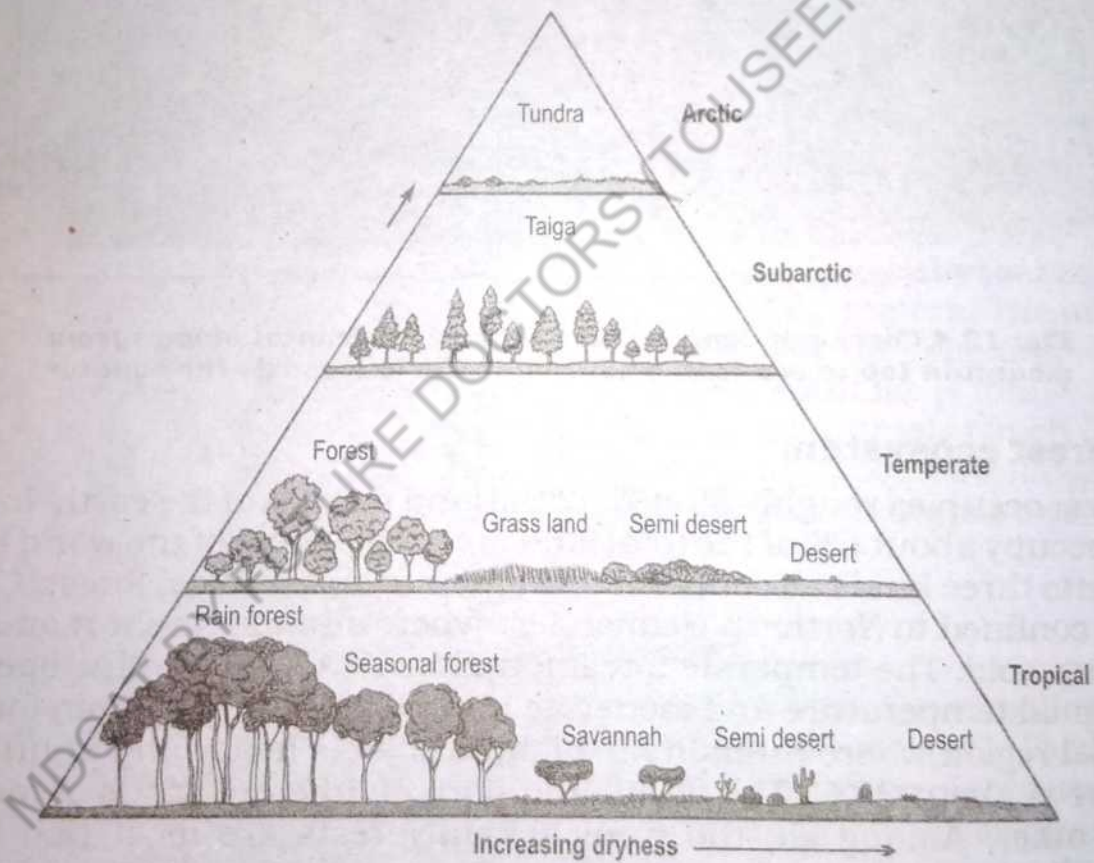


Fig: 12.5 Temperature and rainfall determine biome

2. Coniferous forests:

The conifers are evergreen plants, which belong to gymnosperms group. They are markedly cold resistant. They are found at high altitudes and also at high latitudes. Coniferous forests cover more parts in Northern Hemisphere as compared to Southern Hemisphere. In Northern Hemisphere, the area from Alaska to Central America is heavily glaciated. The winter is very severe and is characterized by heavy snow. The conditions become xerophytic and hence leaves are needle like; plant growth is slow along with decomposition of dead organic

matter of plants and animals. The Pine, Fir and Spruce are dominant species. Dicotyledonous *Bisch willow* and *Populus* are also found in these areas.

Fig: 12.6 Coniferous forest

Coniferous forests of Pakistan:

In Pakistan coniferous forests are found in Kaghan, Swat, Dir, Murree hills and Chilas etc. The main plants of these areas are *Pinus exelsa, Pinus girardiana, Cedrus deodara, Taxus baccata* etc. The ground flora in coniferous forest regions consist of mosses, lichens and members of family Ericaceae, and Rosaceae.

The herbivorous animals of coniferous forests include sheep, deer, wild goat, squirrels and various other insects and birds, whereas carnivores are wolves, leopards and lynx etc.

3. Temperate deciduous forests:

The deciduous forests of temperate region are called temperate deciduous forests. The term deciduous is applied to those plants, which shed off their leaves during winter season. The deciduous forests may be dry, monsoonal (tropical) and moist semi deciduous. In Northern Hemisphere they are found in parts of North America, South America, Eastern Asia, China, Japan and Central Europe, whereas in Southern Hemisphere typical deciduous forests do not exist. Unlike conifers, they require better soil, moderate temperature and average rainfall of about 100 cm. In these regions winters and summer seasons are also found, therefore these areas are largely used for cultivation.

Fig: 12.7 Temperate deciduous forest

Temperate deciduous forests of Pakistan:

The temperate deciduous forests are characterized by broad leaved plants like Beech, Oak and Maple. In Shogran and Neelam valley of Azad Kashmir *Pinus wallichiana* and *Taxus baccata* are dominant. The ground flora is also much richer in these forests due to the fact that light can much penetrate. In summer the ferns and mosses grow in shades, whereas during spring colourful flowers develope.

Many kinds of insects, birds and mammals feed upon plants, while predators of deciduous forests are owls, foxes, bears etc. In cold weather they hibernate or move to other places.

12.3.2 Grassland ecosystem:

Grassland, covers about 19% of earth's surface. Grassland occur where rainfall is too low to support the forest life form but is higher than that which result in desert life form. Generally the rain fall lies between 30 cm to 75 cm. Grassland typically occur in the interior of continents. Grasslands are open land communities with limited moisture conditions, irregular rainfall, sharp seasonal variations and very high radiation. Soil of this region contains large amount of humus. The various components are:

Abiotic substance: These are the inorganic and organic substances found in the soil and atmosphere.

Producers: They are mainly grasses of various sizes and kinds. Beside these a few herbs and shrubs also contribute to primary production. Most of the cereal crops like corn, wheat, oat and barley are produced in these areas. It is due to this fact these are called **bread basket** of the world.

Primary consumers: In grassland the large native grazing mammals are dominant such as buffalo, cow, sheep, deer, rabbit, mouse etc. Beside them there are number of herbivore insects such as grasshoppers, locusts, bugs, beetles etc.

Secondary consumer: These are the carnivores, which include frog, lizard, snakes, birds of prey, fox, jackals, Leopard etc.

Tertiary consumer: Large carnivores of cat and dog families are common.

Decomposers: These are bacteria and fungi of various kind.

Fig: 12.8 The grassland biome

1. Savannah:

The term savannah is applied to the semiforest grass lands of tropical region. Rainfall in such areas is upto 125 cm per year but the dry season is very

long and temperature generally ranges more than 18°C throughout the year. It covers large areas of north and south of Amazon forest East African high lands, South America, South India and Australia.

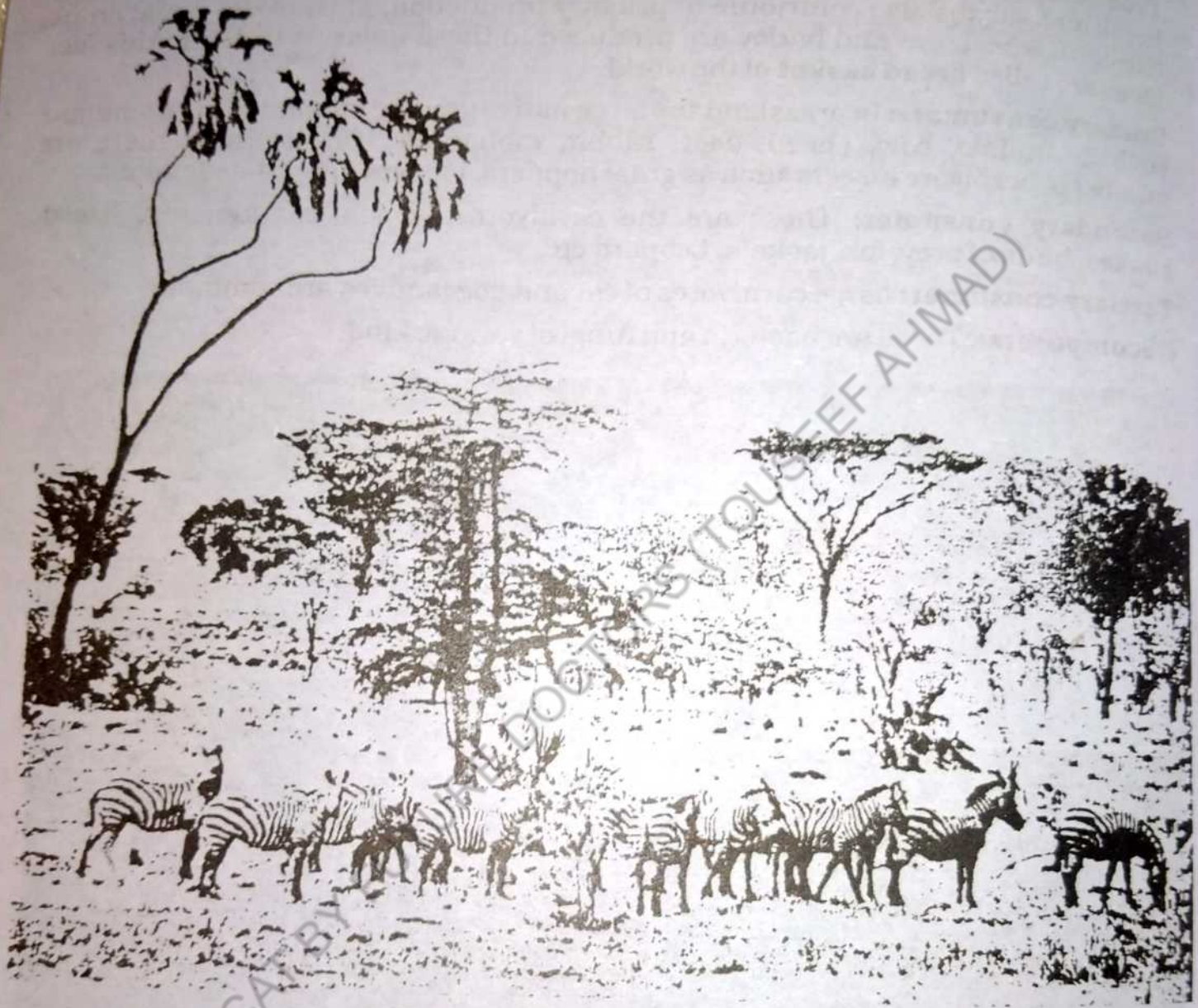


Fig: 12.9 Savannah Biome

Producers: Due to relatively long dry season and uneven distribution of rain fall, forests can not develope, but varieties of plants and animals can be seen. Land is mostly flat and dominated by grasses which in summer may attain a height of 15 feet, like elephant grass. The trees are scattered and bare patches of land can also be seen. Fire play a very important role is ecology of these areas. The trees like *Afzelia africana* and *Danellia oliveri* are fire resistant but grasses usually catch fire.

The land is plane and plenty of grasses and shrubs are available for grazing. Therefore, the size, speed and long sightedness are the main defences of the animals of these areas.

Primary consumers: The primary consumer of these areas are world's large herbivores such as zebras, antelopes, giraffes, elephants and rhinoceroses. The insects like locusts, grasshopper, flies, termites, and ants also form a link in energy cycle. Variety of birds includes the seed eaters such a weavers and the ostrich, which survives due to its speed, watch fullness and keen sightedness.

Secondary and tertiary consumers: The carnivores include lions leopards and vultures.

Long dry season causes change in life pattern. Most of the plants shed off their leaves and use their stored water in unfavourable season, such as **Euphorbia**. The rodents and other animals get shelter under the stones and in holes, snail's retreat into their shells, toads burry themselves into soil and hibernate. The birds migrate to favourable habitats.

12.3.3 Desert ecosystem:

Deserts are defined as lands where evaporation exceeds rainfall. They may found at any latitude wherever rain fall is below 25cm per year and not evenly distributed. Deserts occupy about 17% of land surface of the earth. There are two types of deserts, distinguished on the basis of temperature namely the hot desert and cold deserts. Sahara is the hot and largest desert lies across North Africa to Arabian penninsula. Gobi desert of Mangolia is the coldest. Besides these the deserts are also found in Australia, America, Central Asia, India and Pakistan..

Sahara desert Sonaran desert

Fig: 12.10 Desert biomes

In Pakistan 3 deserts are more famous Thar, Cholistan and Thull. Deserts in Pakistan consist of sandy hills and plains. Besides rainfall, wind also plays an important role in these regions. Vegetation of hills and plains in between two hills differ from one another. It is due to fact that the moisture content in between the hills is slightly higher. Vegetation of sandy hills consist of plants like *Acacia*, *Euphorbia*, *Capparis*, *Calatropis* and *Commiphora* etc. The plants found in

plains are *Prosopis, Capparis, Lycium* etc. Due to sandy soil these deserts could not be used for large scale farming. However, dry farmings of varieties like *Sorghum* and *Bajra* is suitable for these regions.

The desert is a harsh environment where animals and plants have evolved ways to overcome aridity and high temperatures. Desert animals avoid heat by becoming nocturnal in their habits, by seeking shady places; or by spending day in underground burrows. Plants on the other hand, evade aridity by living through dry periods as seed which germinate when sufficient rainfall occur, by storing water in plant body (succulent leaf and stem) or by possessing small narrow, pointed leaves that reduce transpiration. Desert has a wide variability in temperature i.e. hot at day and cool by night. Taking example of Thar desert in Sindh the various component of desert ecosystem are;

Producers: Plants are mostly xerophytic, like *Accacia, Prosopis, Salvadora, Capparis* etc. The ground vegetation is mostly represented by *Calatropis, Panimeum, Tribulus* etc. Some lower plants like lichens and xerophytic mosses may be present.

Consumers: Most common animals are *Tenebrionid* beetles, mantis, grasshopper, centipedes and spider like arthropods. Frog and toad like amphibia. Reptiles like lizards uromastic, calotes, snake like vipers, cobras, kraits and boas, few birds like quail, bustard, partridge, etc are also present. Mammals include, anteaters, hedgehogs, porcupines, bats, burrowing rodents, wild cats, wild boars and foxes.

Decomposers: These are very few, as due to poor vegetation the amount of dead organic matter is scanty. They are mostly thermophilic bacteria and fungi.

12.3.4 Tundra:

Tundra is a biome where the tree growth is hindered by low temperatures and short growing seasons.

There are two types of tundra;

(I) Arctic- tundra (Tundra of high latitudes)

(ii) Alpine tundra (Tundra of high altitudes)

The **Arctic tundra** consists of very large area of land about 5 million acres across Northern North America, Northern Europe and Siberia. The Arctic tundra in Northern Hemisphere is in the form of a wide land, which surrounds the **Arctic Ocean**. Whereas in Southern Hemisphere, there are small patches of land around the **Antarctic Ocean**. The alpine zone above timber line ranging upto ice caps of mountains also possess small patches of tundra and constitute alpine tundra.

The environmental conditions of tundra are not much favourable for producers and consumers both. The temperature is very low all the time. Growing period is very short which lasts for two to three months. In Arctic tundra there is constant day light in mid summer, whereas constant dark in mid winter. The temperature of warmest months do not exceed more that 10°C while it falls very low in winter and reaches upto -57°C. Besides, such low temperatures the wind velocity in alpine tundra reaches upto 160 kilometres per hour and they also have to face intense ultraviolet radiations.

The sub soil in Arctic tundra is frozen from 25-90cm down and is impossible for trees to grow. This frozen soil is termed as **perma frost**. During the summer temperature rise somewhat and the top layer of the perma forest melts leaving the ground very soggy. Alpine tundra, lack tree, but the lower part does not have perma forest and alpine soils are generally better drained than perma forest soils.

The **producers** of tundra ecosystem consist of small perennial herbs and shrubs, which reproduce in very short periods of favourable months. The predominant plants are grasses, mosses, sedges and lichens. They grow on dense mat of peaty humus. The grasses are found in better-drained areas, while southern slopes also possess flowering herbs like *Aconite* and *Geranium*.

Fig: 12.11 Tundra biome

The **productivity** of these areas is very low hence, **consumer** birds and animals are generally migratory. The lemmings, hares, reindeers, oxen, arctic foxes are the primary consumers, whereas snowy owls, foxes and weasels are secondary consumers.

12.4 MAN'S ROLE IN ECOSYSTEM

Being omnivorous man is at the final **trophic level** of the food chain. Thus maintenance of ecosystem can become helpful in solving the food problems. Though the shortest food chains lose very little amount of energy but complicated food webs provide stability to an ecosystem. Because, if a link such as primary consumers are disturbed in a food chain, the whole chain is disrupted; however, food web provides alternate pathways for survival of a community, hence greater number of cross links ensure stability of an ecosystem.

Man's role in ecosystem is of great importance, such as use of **pesticides** is a common practice throughout world. A pesticide not only kill pests, but also their predators. Thus after use of pesticides, pests may redeveloped in an ecosystem, but their natural enemies are not there to control their population, and so they may cause more harm to the community.

Some pesticides like **DDT** (now banned), incorporate in human tissues. The **organic chlorine** 1.0 part per million reduces the fertility of eggs, while 30-40 parts per million are lethal to birds. They enter in tissues through food chains and slowly may accumulate to dangerous limits in consumers. Therefore the excessive use of pesticides is not only harmful for birds but also for plants and animals hence man has a very important role in ecosystem and unbalance in any component may harm the whole ecosystem.

Similarly, the development of new **strains** is very common in pests, which are more harmful at one end while resistant to pesticides at other hand. The best solution of this problem is the use of **biological control**; Malaria is very common in most countries. It may be controlled by draining swamps or by spray of oil etc. but introduction of such **predators**, which feed on mosquito larvae is the best biological control..

Pesticides also affect the biogeochemical cycles. The nitrogen cycle is of most importance, it maintains the ecosystem. The bacteria convert ammonia into nitrites and nitrates. But use of insecticides besides killing pests also kill bacteria responsible for conversion of **ammonia** to **nitrites** and **nitrates**. This reduces the fertility of the soil, which ultimately reduces the productivity of the plants on one hand and increases concentration of ammonia in soil on other hand. The excess ammonia is also harmful for ecosystem, thus increase or decrease of a component disbalances the ecosystem, similarly, excess amount of nitrates and phosphates are also toxic. Because they are drained off from fields to lakes, where they enhance the algal growth and thus increase death and decay of algal population and ultimately increase the consumption of large quantities of oxygen. This suffocate the environment and make it unhealthy for animals, so ultimately lakes may become devoid of animal life.

Phytoplanktons are responsible for production of large quantities of oxygen. If pollutants make oceans unfavourable for them, then a large source of oxygen will not be available to maintain oxygen and carbondioxide ratio; which will have negative effect on human and other living organisms.

12.5 THE FLOW OF ENERGY

The **autotrophs** and **heterotrophs** are essential biotic components of an ecosystem. The autotrophs are mainly green plants, algae and some bacteria. They capture sun light and convert it into chemical energy during photosynthesis and store it as food energy. Heterotrophs depend on the autotrophs for their food, so this food energy ultimately reaches the animals, fungi and other nongreen plants.

The energy which is absorbed by autotrophs is finaly released in space, either by the loss of heat at various trophic levels or finally by the death and decay of living things. Thus in an ecosystem flow of energy remains continuous (for further details see chapter **Bioenergetics** energy flow through an ecosystem).

KEY POINTS

- Two basic components of a pond ecosystem are abiotic and biotic components.
- The biotic components are producers, consumers and decomposers.
- Habitat may be defined as an area occupied by a biotic community.
- The wind velocity moves surface water away from coast, while lower water takes place of the moving away water, this phenomenon is called upwelling.
- Horizontally sea can be divided into neritic and oceanic parts while vertically it is divided into euphotic and aphotic zones.
- The recognisible unit of habitat is called biome.
- The frozen surface soil of tundra is called perma frost.
- Deserts having moderate climatic conditions are referred as cool deserts.
- Grass land biomes are known as bread basket of the world.

EXERCISE

1. Encircle the most correct choice:

i) The producers of a pond ecosystem are
a) Bacteria b) Zooplanklon
c) Phytoplankton d) Fungi

ii) The salt concentration of sea is generally.
a) 3.5% b) 5.0%
c) 4.6% d) 4.0%

iii) The maximum temperature in tundra do not exceeds.
a) 10°C b) 20°C
c) 30°C d) 15°C

iv) The cool deserts is in
a) Pakistan and India b) China and America
c) Australia d) Egypt

v) In grassland biomes the rainfall is usually between
a) 25 to 75 cm b) below 24 cm
c) 100-125 cm d) 125-150 cm

vi) In desert temperature may reach upto
a) 70°C b) 60°C
c) 50°C d) 55°C

vii) The estuaries are places where
a) Lake meet pond b) Sea water reach to pond
c) River meets sea d) Two seas meet.

viii) The oxygen concentration on surface of a river is
a) 1% b) 5%
c) 10% d) More than 10%

ix) Which of the biome has been increased in area by human activities:
a) Savanah b) Grassland
c) Desert d) Coniferous forest

x) Inwhich type of eco system the smallest fraction of nutrients present in soil:
a) Savanah b) Tundra
c) Grassland d) Desert

2. Write detailed answers of the following questions:

i) Describe in detail various components of a pond ecosystem.
ii) What are forests? Describe coniferous forests.
iii) Write a note on grassland and tropical rain forest ecosystem.

3. Write short answers of the followings questions:

i) Why special types of forests are named "temperate deciduous forests"?
ii) Why coniferous forests are so called?
iii) What is biome?
iv) How water from deep sea is brought coastal surface?
v) Distinguish between neritic and oceanic region.
vi) Distinguish between tundra and desert.

4. Define the followings terms:

i) Tundra
ii) Lentic water
iii) Profundal zone
iv) Interdial zone
Vi) Pyrophylus fungi

CHAPTER 13

MAN AND HIS ENVIRONMENT

Human beings occupy highest trophic level in an ecosystem. Due to growing population, human requirement for food and energy is increasing day by day, for this purpose human beings are cutting forests due to which various plants and animal species are in danger and ultimately it can disturb the ecosystem. Similarly, dumping of nuclear wastes and pollutants in atmosphere is hazardous not only for human beings themselves but also for a particular ecosystem.

A balanced inter-relationship between living organisms, including man and environment is essential to maintain life on earth. During last hundred years increased human population and wide spread industrialization societies have created a massive impact of human activities on the environment of earth. Man has destroyed large number of plant communities, natural forests are either cleared for agriculture or for the use of timber. Thus this negative effect of human activities have created large number of deserts, soil erosion, etc. Earth is the only planet where living things including man live. This unbalanced use of environmental resources has created an urgent need of increased awareness to conserve natural resources, which is essential for the survival of human race on this planet.

The emergence of atomic age after world war II has made subject more important. Now a days radioactive waste materials are being produced on a very large scale. They are being dumped in soil or seas, their impact on environment is known to all of us. We cannot afford trial and error procedures because many alterations of the environment are not reversible.

13.1 RENEWABLE AND NON-RENEWABLE RESOURCES

Environmental or natural resources are some type of materials supplied by the environment. These include air, water, food, metals and chemicals etc. used by man. Some of these resources are renewable while others are non-renewable.

Renewable resources are those which can be replenished by physical or biological means. Renewable resources include air, water, soil, wildlife, forests, agricultural products, fish and livestock which support millions of human's all over the world. The important characteristic of living resources are that they can be expected to remain available for ever, if consumed in a sustained manner. More over, tempering with the natural environment and pollution also endanger their continued existence and availability.

Non-renewable resources are those which once used or exhausted cannot be reused, such as fossil fuels (oil, coal and natural gas), metals and industrial materials obtained from the earth. Some parts of the earth are rich in certain non-renewble resources and others are poor. The demand for non-renewable resources is constantly increasing, not only because of population growth but also because the rise in per capita demand. Due to world wide demand of petroleum and natural gas its supplies are declining.

Some renewable resources are as follows:

1. Air:

The blanket of air that surrounds the earth extends outward for many kilometers. Human beings can live in this atmosphere between sea level and about 6000 meters. Air consist mainly of 78% nitrogen, 21% oxygen, 0.03% carbon dioxide, small amount of inert gases (neon, helium, krypton, xenon), dust particles and water vapours. Except inert gases, all these components of air serve as raw material for living organisms. Air contains fertilizing element, nitrogen is essential for growth of all plants i.e. to build proteins and nucleic acid, which are ultimately transferred to consumer by food chain.

2. Water:

Water is the most important fluid on earth, forming the basis of all types of life and is responsible for maintaining the temperature of earth up to bearable limits, as well as behaving as universal solvent. Total water resource of the world has been estimated about 1500 millions cubic kilometers. Of the total water of the world, 93% is in the ocean, 4% in the earth crust, 2% is in glaciers and polar ice caps and only 0.052% is in fresh water lakes, rivers and in atmosphere. The annual production of fresh water by evaporation and precipitation is estimated to be 37,000 cubic kilometers. Fresh water is required not only for domestic purposes including drinking but also for crop irrigation. With these we utilize about 10% water, while industries utilize about 90% of fresh water. Sea water is also of much importance, it is used for preparation of **table salt** and other chemicals.

Soil acts as a reservoir for water. Rain water percolates into the ground and is called as **gravitational water**. It is brought to the surface through springs, wells, seepage and under ground streams. Water that accumulates as a thin film around soil particles is called **capillary water** and the water being imbibed by dry soil particles is called **hygroscopic water**. Rain fall and melting snow replenish the water supply of such reservoirs.

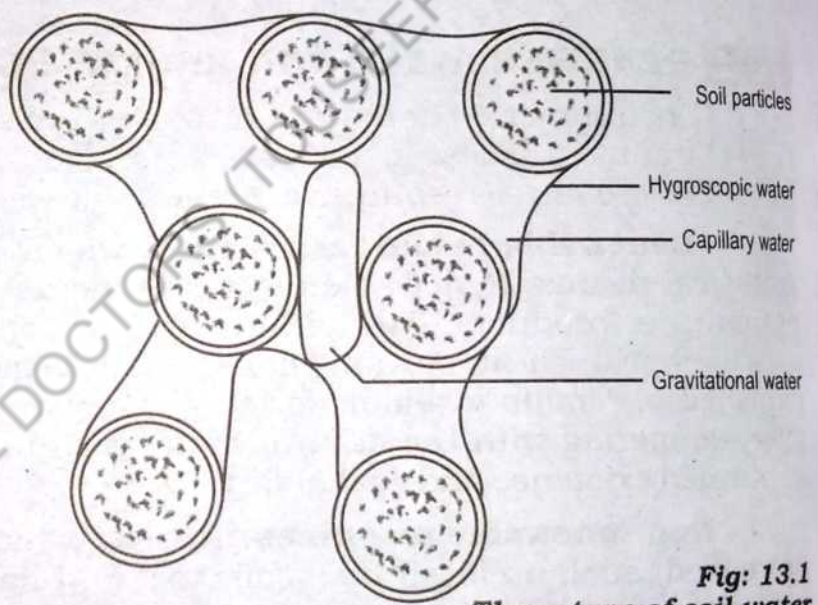


Fig: 13.1
Three type of soil water

Most of the atmospheric water vapours come from sea, but about 14% come from the surface of land, lakes, streams, moist soils and transpiring vegetation. In nature water is a **renewable resource** as it forms an important biogeochemical cycle.

3. Land:

We have already discussed the significance of resources of air and water for man, both are in way related with land. Both the renewable and non renewable resources available for use of man on or in the land may be inorganic and organic. Inorganic resources which are used either directly or indirectly for producting necessary goods are water, mineral fuels, metalliferous ores, building stones and the chemical raw materials. The organic resources are wood, natural grass on pastures, wild game animals etc.

One of the most striking resource of land is its plant cover which depends upon soil and environment and the associated animal life. Forests produce timber, fuel, pulp and natural pastures for animal grazing. Forests and woodlands provide a rich variety of goods e.g. timber, saw wood, pulpwood for pulp, paper. The grazing lands or pastures occupy nearly 23% of the land in the world. Their productivity is

usually low. Unfortunately, both forests and grazing lands are being mismanaged leading to serious consequences.

4. Wild Life:

Wild animals and plants are among our most valuable resources. They play an important role in the balance of nature. Unfortunately man often is not aware of the role of a particular plant or animal in the balance of nature. Wild life is an important resource both for subsistence in developing and recreation in developed countries of the world.

As human population increases and technological development spreads, wild plants and animals and their habitat disappear, thus destroying the natural ecosystem.

13.1.1 Energy:

Energy forms the basis of life-support systems on the planet earth. Like other resource the energy resource may be **non-renewable** and **renewable**. By non-renewable resource we mean those fuels in earth which are found, in fixed quantity, which once consumed, are threatened to be no more available in future. These are **coal, petroleum, natural gas, tar, oil shales** and **nuclear fuels** principally uranium, thorium, deuterium and lithium. The renewable resources of energy are those which are virtually inexhaustible in their duration **solar energy, falling water, wind, wave, ocean currents, tides, temperature gradients** and **plant materials**. A brief discussion of some more important energy resources are as follows:

1. Fossil fuels:

Coal, petroleum and gas are fossil fuels, they fulfill our 95% daily requirements. The fossil fuels got accumulated over a period of hundreds of millions of years as a result of plant material being separated from the energy of the biosphere. **Coal** is derived from the oxidized carbon of plant tissues.

Petroleum and **natural gas** have been very important additions to man's energy resources. The petroleum and natural gas are materials of organic origin, derived from decomposition of plant materials, primarily marine.

The major oil and gas fields in Pakistan are located in Potohar (Khor), Badin and Sui.

2. Nuclear energy:

Nuclear fission involves splitting of certain heavy elements into lighter ones, resulting into the conversion of small mass of the element into energy. It takes in a nearly 7 hours to fission 1 kg of nuclear fuel, releasing 79 kj as heat at a rate of 3000,000 kilowatts. To achieve the same amount of energy we would require combustion of about 3 million kg of coal.

The real difficulties with fission be not in the supply of fuel, but due to the **environmental hazards** caused by it. Large quantity of radioactive waste is produced and thus cause environmental pollution.

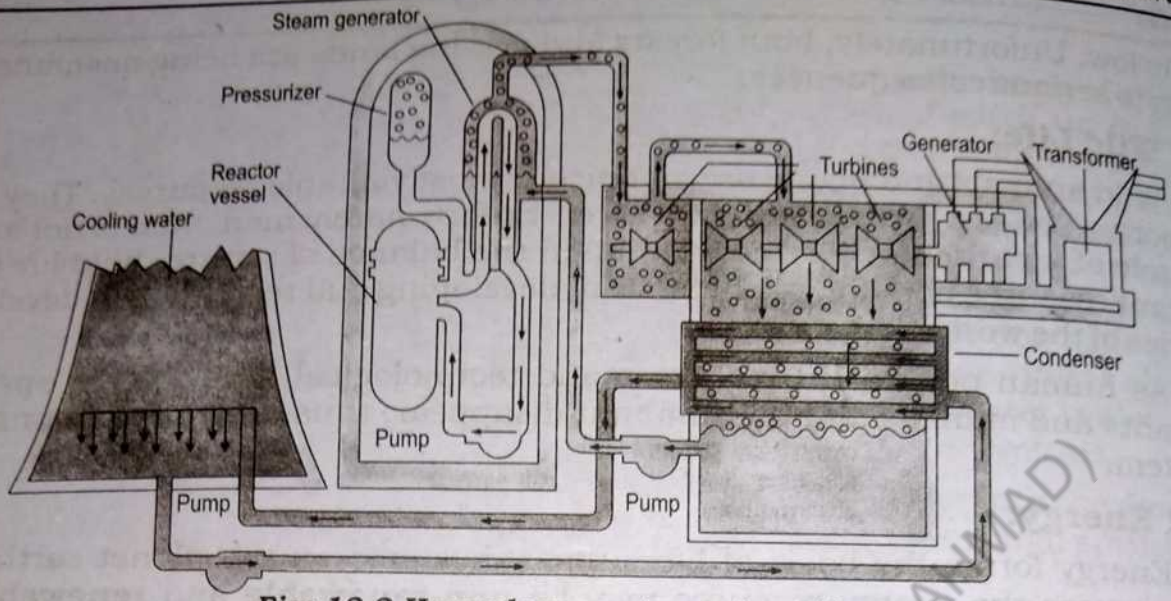


Fig: 13.2 Hazardous waste produced by nuclear power plant

3. Geothermal energy:

Heat produced by radioactive material deep beneath the surface of the earth is geothermal energy, which is trapped in the earth. It is non renewable type. Heat produced in the earth's interior may provide a source of usable energy. The internal heat of our planet manifests itself on the surface in the form of volcanic activity,

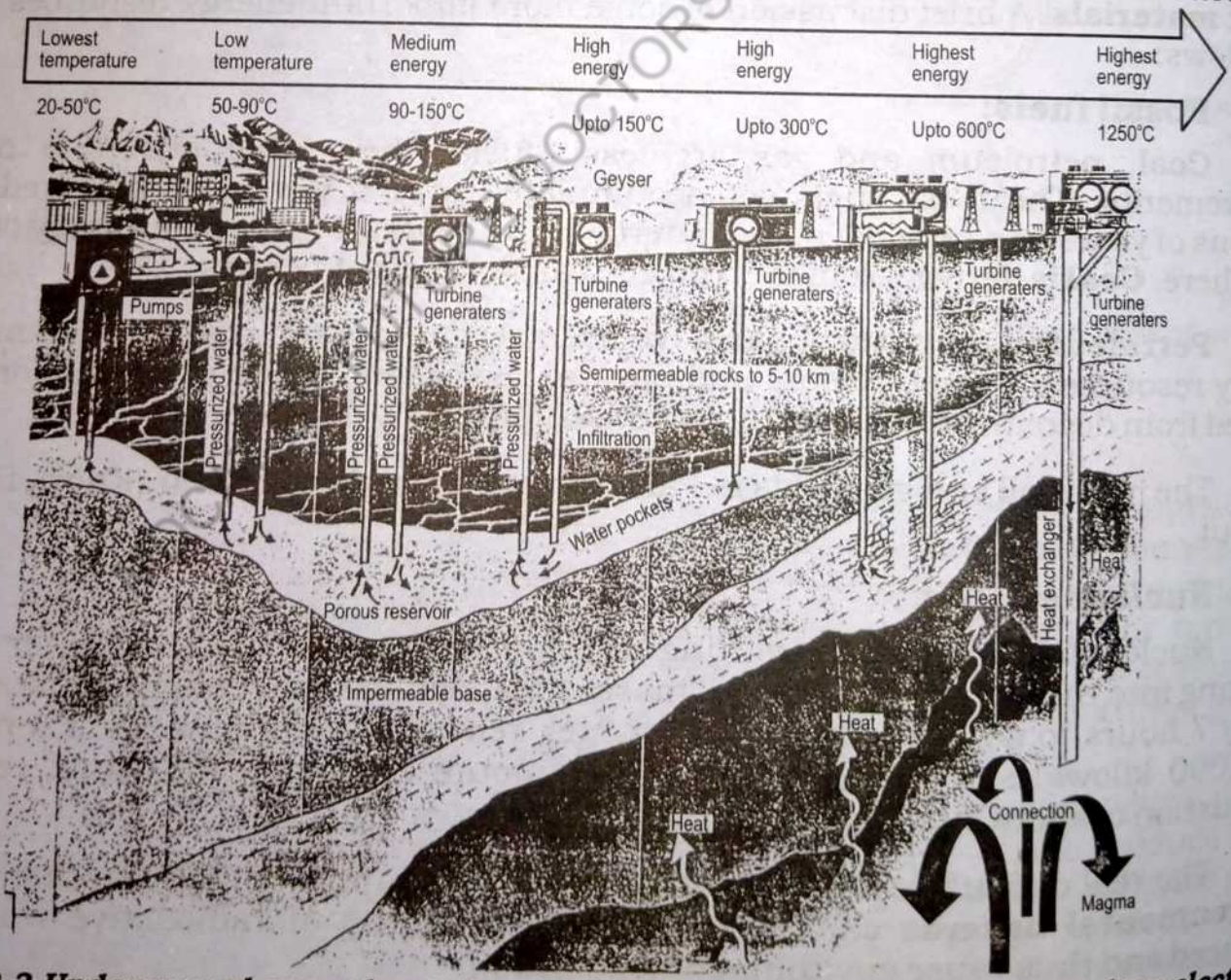


Fig: 13.3 Underground super heated water is pumped upto turbine that produce electricity

super heated water or steam escaping from under the ground (geysers and hot springs).

4. Solar energy:

The solar energy is a renewable resource and we would continue receiving it for the remaining lifetime of the sun for billions of years. The amount of energy received in a fixed time is fixed. As the solar energy is received with breaks e.g. during day and not during night, technology is needed to store it for night and bad weather.

5. Solid wastes:

Refuse in the lanes, litter on roadsides, discarded cartons, tins, polythene material, cracked bottles, agricultural and industrial wastes have attained such a huge magnitude that they now form an important threat to man by pollution of air and water and many times by breeding bacteria and other animals that cause human health problems. In most areas the arrangements for waste disposal are either ignored, inadequate, in-efficient or old-fashioned.

One of the most promising concept in solid waste disposal is their use in energy generation. Certain kinds of solid waste material such as farm and animal manure, crop residues and sewage however can be converted into fuel, called **biogas**. Biogas plants are being utilized on small scale in Pakistan and third world countries.

6. Wind, wave and ocean thermal gradients:

The wind, waves and ocean thermal gradients are indirect sources of solar energy. The amount of energy in wind, waves and thermal gradient has been estimated between 250 to 2500 billion kilowatts. Though the amount of energy is huge, yet it is not likely that even 1% of this energy could be effectively put to human use. These sources need consideration due to their long duration.

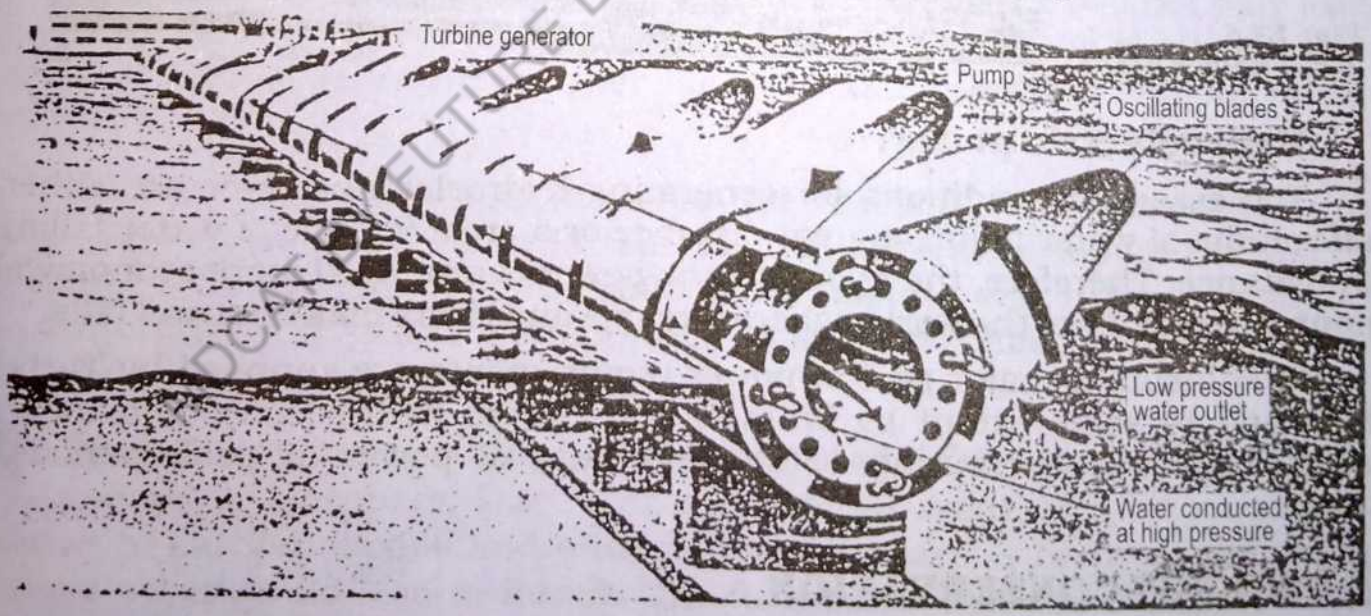


Fig: 13.4 Generation of energy from wave motion

Ocean thermal gradient energy conversion is elaborate solar technology based on the difference in temperature between surface and deep waters. In tropical sea water, the surface temperature is commonly 25°C, while at a few hundred meters depth, the temperature is 5°C. Heat is conducted from higher to

regions of lower temperature. The thermal gradient difference is used to runs ammonia turbines for production of energy.

7. Tidal power:

Tides have been in use for a long time as a source of energy for operating small mills, e.g for grinding corn in coastal areas in some countries. The modern world is interested in generating large amount of electricity from tides and use it for inland (Fig. 13.5).

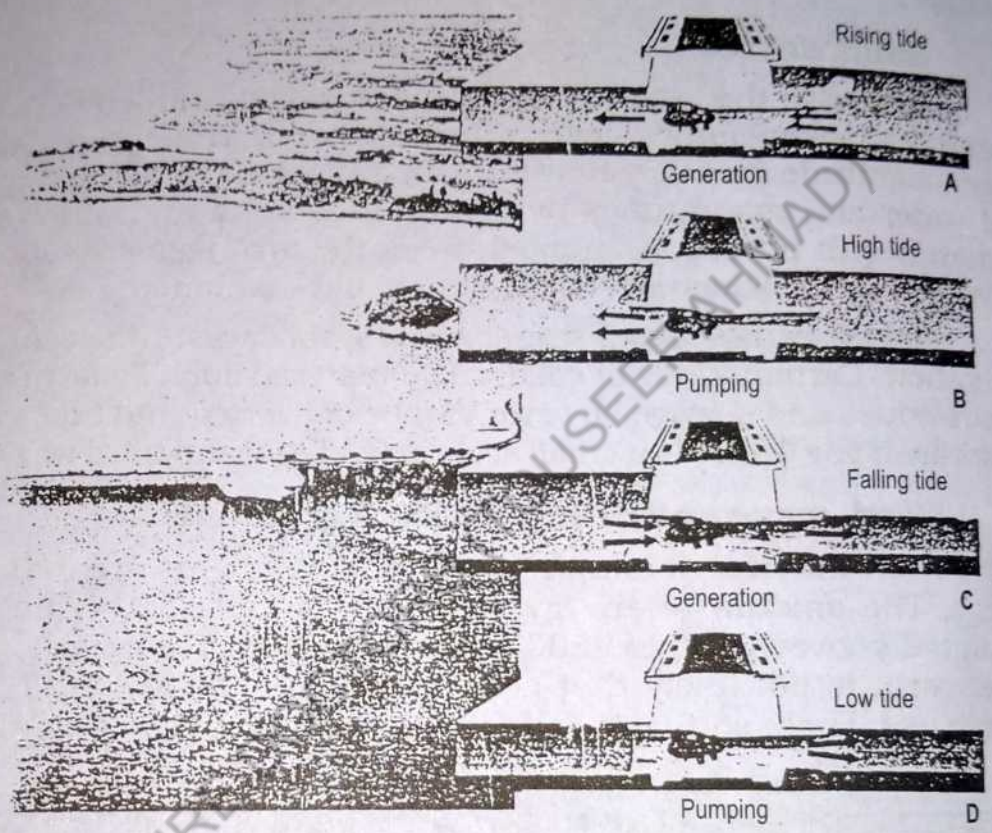


Fig: 13.5
Tidal power plant

8. Hydroelectric power:

The essential conditions for generating hydroelectric power are either a small volume of water falling a great distance or a great volume of water falling a short distance. Therefore, the hydroelectric power is produced more economically in mountain regions of the world, where streams and rivers make natural falls.

In Pakistan a major part of power requirements are supplied by Tarbela, Mangla and to some extent by Warsak and Dargai hydroelectric schemes. At present WAPDA is generating 4300 megawatts of power at peak periods in Pakistan.

13.2 ENERGY CONSERVATION

From the last 150 years human beings are using fossil fuel as cheapest source of energy for domestic and industrial uses, but now this source being non renewable is exhausting at one end while on the other hand it has become very costly. Similarly, the nuclear power also has its own demerits, the disposal of nuclear waste and safe use of nuclear power plants is also a great problem.

Therefore, we have to develop alternate resources for generating electric power such as solar and wind energy.Besides, generation the proper use of present resource has become more important.

It has been estimated that about 75% electricity produced is being wasted through the use of inefficient modern machines and appliances such as motors, heaters, air conditioners, refrigerator etc. These appliances not only waste electricity but are also responsible for **global warming** by increasing the temperature of the earth. We use light bulbs in our homes, streets and factories, a new fluorescent bulb consumes 20% of light electricity and is more durable than normal bulb, so we should choose correct appliance for daily use. It will not only save money but also electricity.

13.3 MAN'S IMPACT ON ENVIRONMENT

Degradation and depletion of resources:

The man's activities on earth are continuously not only altering the environment particularly the non renewable resources but also degrading and depletion them. These activities are making more difficult the survival of human race on this living planet.

Fossil fuel which has been accumulated over a period of millions of years is being consumed on a large scale and yet no other alternative has been developed. Thus a day may come, when there will be no fuel.

Forests provide us timber for making homes and furniture, fire wood and medicines. Wood from forests is cut every year and if this ratio is maintained all of the rain forests will be gone in about 30 years. This practice will not only lead to environmental disbalance but it will also make extinct various plant and animal species. At present several species per day are becoming **extinct** and this rate may go higher in future.

Nuclear plants are also threat to our environment. **Chernobyl** nuclear power plant blewup in 1986 in Russia. The radiation dose was much lower but significant as more than 5000 to 75000 cancer deaths were expected due to fact that large number of people were exposed to radiations and its after effects were noted after several years.

Man's activities on this planet are **modifying** rather **deteriorating environment** of biosphere. Due to changes in our mode of transportation, the emission of carbon dioxide and other industrial gases is responsible for global warming which could lead to **floods.** The fungicides, insecticides used on crops ultimately reach in soil water and hence soil environment is also changing which could effect plant growth. This degradation of environment is a serious problem at present. We should think about it and must adopt such practices that further modification of environment is stopped.

13.3.1 Population and food:

Though there exists a wide range of variation in the rate of growth of human population in various countries, but the overall world population increases from nearly 4 billion in 1975 to nearly 5 billion in 1987. The more developed countries, in the last 20 years have grown in population by 23%, whereas the less developed by 62%. With growth rate of 2% per year the world population may become 10 billion by 2020, and 20 billion by 2055. In Pakistan, the population is increasing at the rate of 3% per annum which is very alarming. It is disturbing supply and consumption balance and planing of various development projects in the country.

Though increase in food production is made possible through advance agricultural techniques. Yet the rapidly increasing burden of population is making it useless, resulting in food shortage specialy affecting 3rd world countries..

The tragedy of **malnutrition** goes hardly un-observed any where even to an occasional observer. Advanced symptoms of protein malnutrition like swollen bodies, reddish brown brittle hair are well known.

13.3.2 Need of population control:

Human population is growing explosively at a rate of 1.8% per year thus 95 million people are added every year so the population will double in next 40 years. The world population at present is about 6 billion and it will become 20 billions by 2055 as stated earlier.

In view of limited resources, it is essential to control fast growth of human population. In some parts of the world like Thailand and Mexico, there is decline in birth rate. If other countries also adopt such practices slow down growth rate then we will be able to provide food to our coming generations.

13.4 EFFECTS ON AGRICULTURE

Increasing human population needs more food, for this reason more people are needed for agriculture alongwith more land. On our planet, there is about 70% water, thus requirement of land is fulfilled by cutting forests, shifting agriculture i.e. clearing a patch of forest, growing crops for few years and then moving on, has destroyed large areas of forests. This activity is responsible for **environmental change**. Similarly the use of fungicides and other chemical sprays on crop are responsible for land pollution. The continuous use of land has also declined the fertility of the soil.

13.5 DEFORESTATION AND AFFORESTATION

Cutting of forests for agriculture, fire wood etc. is called deforestation. The deforestation is responsible for degradation. Pakistan is situated in an area where forests occupy very small part of our land, it is due to this reason government plans include large scale plantation every year. New plantation i.e. afforestation is the only solution to increase of our forest area.

13.6 POLLUTION

Today, man is facing one of the most horrible ecological crisis of his time i.e. pollution. The **pollution** is an undesirable change in the physical, chemical or biological characteristics of air, land, and water that may harmfully affect human

life or that of desirable species. The environment of world is gradually getting polluted. Its pace has increased considerably after the industrial revolution of the last century.

Generally, there are various kinds of pollution such as pollution of air, water, and land. In addition to these, there are also other kinds of non-material pollution such as radiation pollution, noise pollution and thermal pollution.

1. Air pollution:

When due to some natural processes or human activities, the amount of solid waste or concentration of gases other than oxygen increase in the air, which normally has constant percentage of different gases in it, the air is said to be polluted and this phenomenon is referred to as air pollution. Air pollution is one the most dangerous and common kind of environmental pollution that is being reported in most industrial cities of the world.

Another major source of air pollution is the particulate and gaseous matter released by the burning of fossil fuels such as coal, petroleum etc. **Particulate pollutants** includes large number of things such as simple carbon smoke, road dust, particles of metals, soot tars, mineral dust resins, pollens, aerosols, oxygen compounds, halogen compounds and radio active substance.

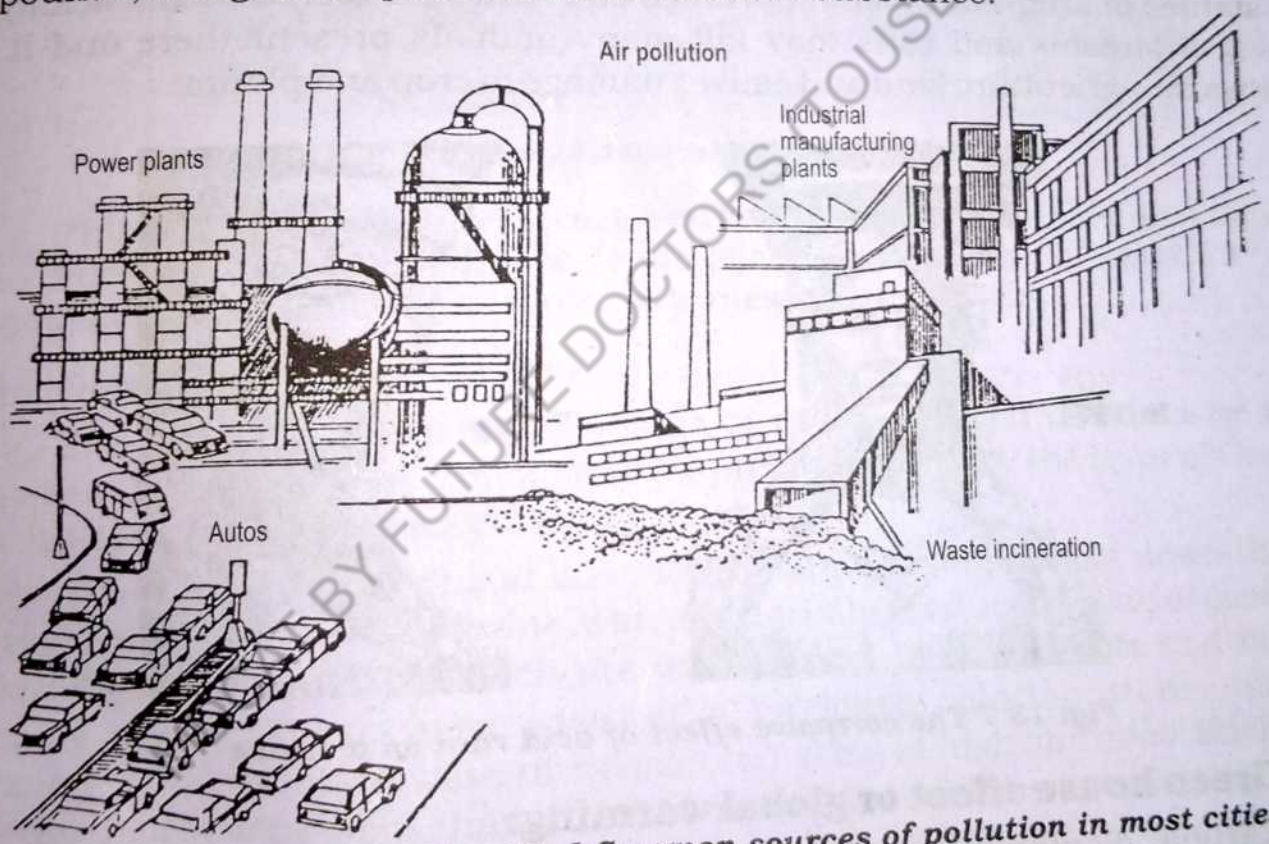


Fig: 13.6 Common sources of pollution in most cities

Stationary combustion of plants and transport vehicles burn fuel at very high temperature and produces nitrogen oxide (NO_2). Under the energy supplied by the sunlight, the nitrogen oxide (NO_2) combine with gaseous hydro-carbons to form a variety of secondary pollutants called **photochemical oxidants**. These oxidants together with solid and liquid particles in the air are very effective in the scattering of light, that causes the milky-gray haze characteristic of the **photochemical smog**. This type of smog causes irritation of lungs and eyes.

Other gaseous pollutants are carbon monoxide (CO) and sulphur dioxide (SO_2). Carbon monoxide is a poisonous gas produced by the incomplete burning of carbon fuels. A great bulk of carbon monoxide comes from the gasoline powered motor vehicles. Sulphur dioxide (SO_2) is mainly produced by burning of coal and oil bearing sulphur.

(i) Acid rains:

Power stations and other industrial units run by burning of coal processes emit carbon dioxide, sulphur dioxide and nitrogen oxides into the air. In the atmosphere, these gases react with moisture to form dilute sulphuric acid.

$$SO_2 \xrightarrow{\text{Water vapours}} H_2SO_4 \text{ (Sulphuric acid)}$$

$$NO_2 \xrightarrow{\text{Water vapours}} HNO_2 \text{ (Nitrous acid)}$$

$$CO_2 \xrightarrow{\text{Water vapours}} H_2CO_3 \text{ (Carbonic acid)}$$

These then return to the earth with rain water and is known as **acid rain**. The acid rain causes many respiratory diseases in man. Sulphuric acid pollution is not only a health hazard, but also destroys many man made structures, metals and statues of archaeological importance etc. Acid rain increases the acidity (pH values) of streams and thus may kill many animals present there and it also destroys the agriculture land and causes damage to crop and plants.

Fig: 13.7 The corrosive effect of acid rain on a statue

(ii) Green house effect or global warming:

Carbon dioxide plays a critical role in regulating the earth's surface temperature. Concentration of carbon dioxide is increasing in the air at an alarming rate due to burning of fossil fuel. Carbon dioxide allows the sun rays to pass through the atmosphere but prevents the long wave radiations (i.e. infra red heat radiation) reflected by earth from escaping into outer space and redirects heat back towards earth, and thus temperature of the atmosphere gradually starts increasing.

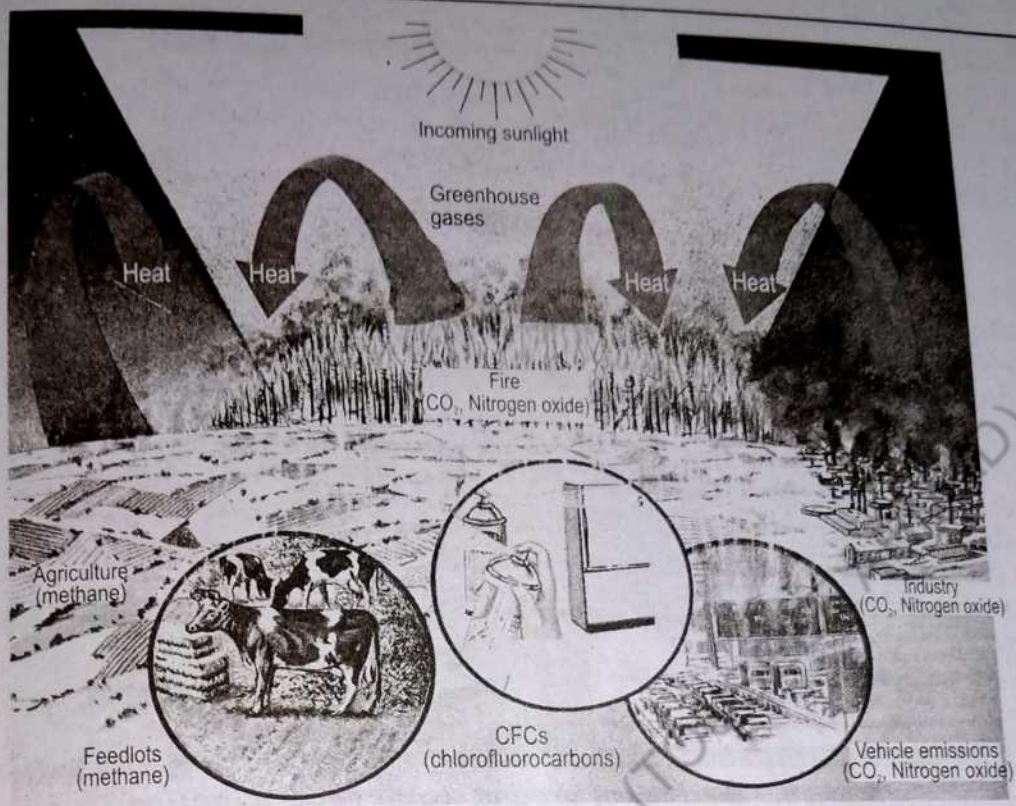


Fig: 13.8 Greenhouse effect

This rise in temperature, form green house effect has a disastrous impact on agriculture and eventually on sea levels because of melting of polar ice. It also causes heavier rains, floods, severe hurricanes and tornadoes.

(iii) Depletion of Ozone layer:

The harmful ultraviolet radiations of the sun which could cause serious damage to human, animal and plant lives are filtered out by the layer of Ozone (O_3) which acts as a protective shield for life on earth.

The release of chlorine atoms into the atmosphere breaks down the ozone shield. A major source of chlorine is an industrially produced group of gases called **chlorofloro-carbon** (CFC) which are widely used as refrigerants and industrial foaming agents. These inert gases (CFC) release chlorine atoms under the influence of intense short wave ultraviolet radiation at high altitudes. Each atom of chlorine reacts with more than 100,000 molecules of ozone, converting ozone to oxygen. Due to the depletion of ozone layer, ultraviolet light penetrates and reaches at the earth's surface and causes skin cancer and many other lethal effects on many organisms including man.

2. Water pollution:

The term water pollution is referred to any type of aquatic contamination. Pollution of fresh and sea water is caused by three major sources: (a) domestic, (b) industrial and (c) agricultural.

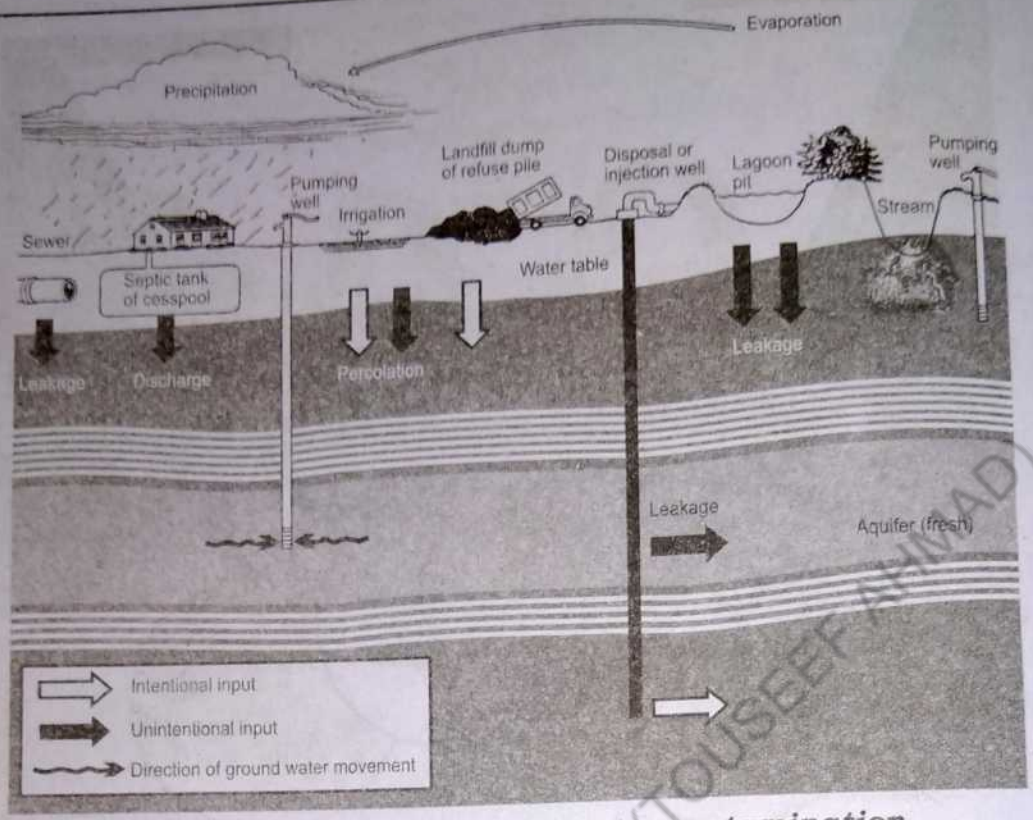


Fig: 13.9 Sources of ground water contamination

Pollutant entering water mainly come from industrial, municipal and agricultural wastes, erosions, oil spills, mine drainage and wastes from fishing vessels. Many of the wastes discharged by industry are toxic, particularly those from paper, leather, chemicals, petroleum and steel industries. Contamination of fresh waters and shallow off shore seas by sewage is of common occurrence. Sewage includes mostly biodegradable pollutants such as human faecal matter, animal wastes and certain dissolved organic compounds (e.g. carbohydrates, urea etc.) and inorganic salts, such as nitrates and phosphates of detergents, and sodium, potassium, calcium and chloride ions. Under natural processes most of the biodegradable pollutants of **sewage** are rapidly decomposed, but, when they accumulate in large quantities, they create problems. Poultry feeding operations, animal wastes and fertilizers are the source of agricultural pollution of water. Water leaking from irrigated fields, where nitrogenous fertilizers are used, are a source of serious water pollution. Offshore oil leaks causing water pollution are recognized as world wide problem. Due to oceanic pollution, the marine biota has been seriously affected.

Industrial effluent:

Toxic chemicals are agents of water pollution, originate in industrial operations i.e. acid mine, drainage, surface erosion from strip mines, washing of herbicides and insecticides, radioactive fall out from atomic explosion and commercial accidents such as oil spills or rupture of chemical tanks.

Insecticides, herbicides and fertilizers:

In agriculture, there is common use of insecticides for killing insects, herbicides for destroying undesirable herbs and fertilizers two increase in crop production. These substances ultimately reach the water table and reuse of soil water thus become injurious for health.

Eutrophication or Algal bloom:

The lakes on the basis of their production of organic matter can be divided into two types i.e. **eutrophic** and **oligotrophic** lakes . The eutrophic lakes contain abundant supply of minerals and organic matter. The oxygen requiring organisms rapidly utilize the available oxygen and thus the oxygen level is very low in such lakes. The oxygen depletion also converts **sulphates** and **nitrates** into toxic materials like **hydrogen sulphide** and **ammonia**. The human activities like adding of minerals and organic wastes also speed up this process. However, the oligotrophic lakes have less amount of nutrients and they are deeper than eutrophic lakes, hence rich in oxygen. Excess **phosphorus** from sources like fertilizers, sewage or detergents lead to harmful effects and promote the algal growth called **algal bloom**, which deplete the oxygen and causes death of aquatic animals.

3. Land pollution:

Land pollution is caused by solid wastes, which include household trash, sewage sludge, garbage, agricultural residues and industrial wastes. Those solid wastes containing substance that cause human illness and sometimes even death are called hazardous wastes. Hazardous wastes include mercury, cadmium and beryllium which can accumulate in various organs, interfering with normal enzymatic actions and causing various illnesses including cancer. Nuclear wastes include radioactive elements which are dangerous for human health causing ailment including cancer.

13.7 NON-MATERIAL POLLUTION

1. Radiation pollution:

Radiation pollution is -a-new problem. The cosmic radiation from the sun, X-rays, radio active isotopes of elements in the earth and by products of atomic explosions are principal source of radiation. These nuclear by products release energy, which is ionized and can disrupt biological molecules. Some radioactive isotopes emit gamma rays, which can damage living tissues.

2. Noise pollution:

Another serious threat to the quality of man's environment is noise pollution. Noise can be defined as **unwanted sound**. Noise levels are measured in **decibels** (Fig. 13.12). According to decibel scale, noise above 80 decibels is considered as loud uncomfortable and dangerous to health. Noise is primarily a feature of big cities. High intensity sound or noise pollution is caused by many

machines in factories, industries and mills, different kinds of auto and motor vehicles, air crafts, motor boats, ships, loud speakers, social gatherings, loud pop mucic, supersonic air crafts etc.

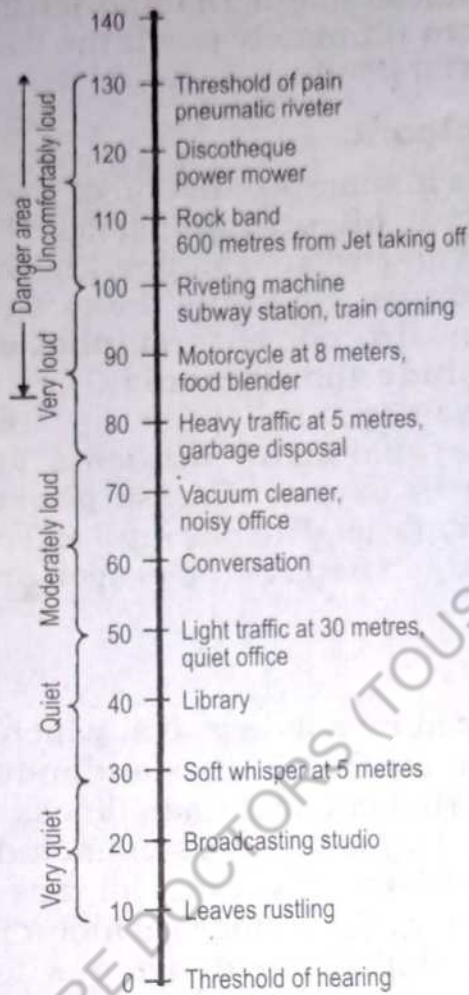


Fig: 13.10 Decibel scale and common noise sources

Constant noise damages people physically and mentally. High intensity sound when continued for long period of time not only disturbs but also permanently damages hearing. Offices, industries and crowded places where constant noise prevails can produce headaches, fatigue, nausea and makes person irritable.

13.8 PROTECTION AND CONSERVATION OF ENVIRONMENT

An unprecedented growth rate of human population in recent history of the planet is causing considerable stress on the environment. The biosphere is unable to respond conservation efforts at its own. The production of enormous amounts of waste materials including radioactive wastes of modern world are increasing the pollution level.

Thus, the application of principles of biology is the only solution to solve various environmental problems and so as to achieve a productive and stable world, which is necessary for future generations.

13.8.1 Management of Natural resources:

The renewable and non renewable resources of nature are essential resource for survival of living organisms on earth. Air, water, food, land, forests, fish and wild life are **renewable resource**. Nature is constantly replenishing them and if they are properly used, they would never be depleted.

13.8.2 Pollution control:

Pollution is a serious problem that exists all over the world. Despite use of improved systems of disposal of sewage, our lakes, rivers and streams and ground water is becoming polluted on a large scale by the modern fertilizer, insecticides and pesticides which ultimately reach the ground water and make it unfit for human consumption, thus there is a need to develop methods of **biological controls**. There are certain bacteria which may be helpful in control of plant pests. *Bacillus thuringensis* is one of them, which kills the caterpillar of insects if spread on crop, but it is not harmful to human beings. Similarly nodulated roots posses nitrogen fixing bacteria, they are source of nitrogen for leguminous plants. If such bacteria are also introduced in other plants, there will be no need of nitrogen fertilizer and hence we can avoid pollution due to fertilizers. Polluted air contains carbon monoxide, carbon dioxide and oxides of nitrogen and sulphur, these are produced by industries, vehicles and other engines. Due to these gases acid rain and green house effects are developed. If their emission is controlled no such pollution will take place.

13.8.3 Recycling of Wastes:

Waste disposal is one of the biggest problem of cities, hundreds of tons of solid waste materials are produced daily, it contains large number of materials which can be recycled, thus hazard of pollution can be reduced.

13.9 CONSERVATION OF ORGANISMS AND THEIR HABITAT

Various ecosystems collectively constitute biosphere and there is a delicate balance between living organisms and environment. Organisms survive in their particular habitat, which include aquatic and terrestrial. The destruction and disturbance of habitat is accompanied by **extinction** of major proportion of all plants, animals and microorganisms species. The complex ecosystems built up in billions of years are now being destroyed. Due to ignorance, we are engaged in one time consumption of this natural resource. This practice must be stopped. The tropical rainforest has highest rates of net primary productivity of any plant community on earth, it is thus essential that they may not be harvested the current speed but in a sustainable way.

The selection of proper sites for building of **reservoirs** and **dams** to store immense quantities of water and its filtration is of great importance, they should be much separated from sewage treatment plants. The selection of proper site for dumping of urban and industrial wastes is also of much importance. These wastes could contaminate underground water. Conservation of environment for our future generations is the call of the day.

13.10 HEALTH AND DISEASE

Health as defined by W.H.O. as a condition of physical and mental well being. On the contrary disease is an abnormal condition in which an organ or part of an organ does not perform its normal function.

Diseases can roughly be categorized as infectious, parasitic, nutritional, genetic (Congenital and non-congenital), aging associated (degenerative), etc.

Some of above mentioned categories of diseases with reference to man are shown in the following table.

Category of the disease	Example	Cause of disease	Transmission
INFECTIOUS DISEASES (Caused by a specific microorganism) **(a) Viral Diseases**	Influenza	Influenza virus A, B, or C.	Air- borne droplets
	AIDS	HIV	Sexual contact; sharing hypodermic needles; mother to child; blood transfusion.
	Hepatitis	Hepatitis viruses A, B, C, etc.	Infected water or food; blood transfusion; sexual contact; sharing used hypodermic needles.
	Chicken pox	Varicella-zoster virus	Air-borne droplets; direct contact.
	Rabies	Rabies virus	Bite from infected dog.
(b) Bacterial Diseases	Tuberculosis	*Mycobacterium tuberculosis*	Air-borne; infected cow's milk.
	Typhoid fever	*Salmonella typhosa*	Food or drink contaminated with infected feces.
	Pneumonia	*Streptococcus pneumoniae*	Air-borne droplets.
	Cholera	*Vibrio cholera*	Food or water contaminated with sewage containing *V. cholera*.
(c) Fungal diseases	*Tinea corporis* (Ring worm of body)	A group of Dermatophytes	Contact with infected person, animal
	Tinea versicolor	Another group of Dermatophytes.	Air-borne, contact.
	Tinea pedis (Athelete's foot)	Dermatophyte	Air-borne, contact.

Category of the disease	Example	Cause of disease	Transmission
(d) Protozoal diseases	Malaria	*Plasmodium spp.*	Bite of infected female Anopheles mosquito.
	Amebiasis	*Entamoeba histolytica*	Food or water contaminated by cysts of Entamoeba.
	Leishmaniasis (Cutaneous leishmaniasis)	*Leishmania spp.*	Bite of infected sand-fly (Sehraee Makhee)
	Trypnosomiasis (African sleeping sickness)	*Trypanosoma spp.*	Bite of infected Tsetse fly.
Parasitic diseases (a) Helminthic diseases	Taeniasis	*Taenia saginata*	Consumption of infected under cooked beef.
	Hydatid diseases	*Echinococcus granulosus*	Ingestion of cyst released in feces of dogs.
	Enterobiasis (Pin worm infection)	*Enterobius vermicalaris*	Ingestion of eggs released at pre-anal region.
	Ascariasis	*Ascaris lumbricoides*	Ingestion of eggs.
(b) Nutritional diseases	Night blindness	Deficiency of Vitamin 'A'	
	Beri-Beri	Deficiency of Vitamin 'B_1'	
	Scurvy	Deficiency of Vitamin 'C'	
	Rickets	Deficiency of Vitamin 'D'	
Nutritional diseases	Anemia	Deficiency of Iron	
	Prolong Bleeding	Deficiency of Vitamin 'K'	
	Tooth decay	Deficiency of florine	
	Goitre	Deficiency of iodine	

Category of the disease	Example	Cause of disease	Transmission
Genetic disorders (congenital)	Sickle Cell Anemia	Abnormal haemoglobin	
	Haemophilia	Deficiency of a blood protein - factor VIII	
	Albinism	Complete or partial loss of pigmentation in the skin, eyes, hair.	
(Non-Congenital)	Asthma	Allergies	
	Diabetes mellitus	Insufficient or absence of insulin	
Aging associated diseases	Osteoarthritis	Degeneration of the cartilage of joints	
	Alzheimer's disease	Degeneration of neurons of brain	

Prevention and Control of diseases:

Pathogens are responsible for various infections, but for their spread environment like air, water and vectors such as insects, actual contact etc. also plays an important role. Thus for their control, preventive measures, eradication of vectors and pathogens alongwith their medical treatment are important.

Preventive measures:

For the control of infectious diseases preventive measures are applied on personal living, in the surrounding and at community level.

Control of vector:

Mostly vectors are insects, they may be eliminated by the use of insecticides or by the biological control. Repellents may be used to avoid contact with the vectors.

Control of pathogens:

Particularly during surgical operations, an atmosphere free from pathogens is required. For this purpose variuos methods are used to control pathogens, such as disinfectants, antiseptics, thermal treatments, UV radiation and treatment of the infected individuals, etc.

KEY POINTS

- Natural resources are of two types i.e. renewable and non-renewable.
- Nitrogen found in protoplasm comes from the food we eat and not from environment.
- Coal, petroleum and gas are non-renewable fossil fuels.
- The renewable source of energy is solar energy, falling water, winds and waves etc.
- In Pakistan major part of power requirements comes from Tarbela and Mangla dams by hydroelectric power.
- Pollution is of four types i.e. Air, water, land and non-material (radiation noise, thermal).
- Disease is a deviation from normal mode of life.
- The humidity and over crowding favours the spread of air borne diseases.
- Sewage is main cause of water borne diseases.
- Small pox, rabies, yellow fever, unfluenza are viral diseases.
- Cholera, typhoid, pneumonia, tuberculosis are bacterial diseases.

EXERCISE

1. Encircle the most correct choice:

i) The non-renewable resources of the following is
a) Wild life b) Forests c) Water d) Coal

ii) The most safe and cheap source of energy is
a) Nuclear energy b) Hydroelectric
c) Petroleum d) Coal

iii) The gas responsible for global warming is
a) Oxygen b) Nitrogen c) Carbon dioxide d) Ozone

iv) The gas responsible for depletion of ozone is
a) Oxygen b) Carbon dioxide c) Nitrogen d) Chlorine

v) Eutrophication in lakes and ponds is due to growth of
a) Bacteria b) Plants c) Algae d) Fungi

vi) The anemia is due to deficiency of
a) Calcium b) Iron c) Iodine d) Vitamins

vii) Night blindness is caused due to deficiency of
a) Vitamin K b) Vitamin A c) Vitamin C d) Minerals

ix) Sickle cell anaemia is a disease caused by
a) Abnormal gene b) Fungus
c) Bacteria d) Virus

x) Osteoarthritis is a:
a) Bacterial diseases b) Degenerative disease
c) Viral disease d) Protozoan disease

xi) Noise is considered as sound beyond
a) 30 decibels b) 50 decibels
c) 80 decibels d) 10 decibels

xii) Which of the following is responsible for acid rain?
a) CO_2 b) SO_2
c) NO_2 d) All of these

xiii) The major power requirements of Pakistan are accomplished by
a) Nuclear energy b) Solar energy
c) Hydro electric power d) Tidal power

2. Write detailed answers of the following questions:

i) What are renewable and non renewable resources? Describe in detail the fossil fuels.
ii) Fossil fuels are non renewable resources of energy. Describe various alternatives or renewable resources of energy.
iii) What is pollution? Describe non material pollution in detail.
iv) What are infectious diseases and how are they transmitted?
v) Describe in detail prevention and control of diseases.
vi) Suggests some ways to control pollution so that a lay man may become aware and play important this part in this regard.

3. Write short answers of the following questions :

i) Define renewable and non renewable resources.
ii) Write a short note on energy conservation.
iii) What are advantages and disadvantages of nuclear energy?
iv) Write a short note on acid rain, green house affect and depletion of ozone layer.
v) What is eutrophication? What are its disadvantages?.
vi) Distinguish between renewable and non-renewable resources.
vii) What are deforestation and aforestation?

Prepared by the Sindh Textbook Board, Jamshoro and prescribed by the Boards of Intermediate and Secondary Education, Karachi, Hyderabad, Mirpurkhas, Larkana and Sukkur.
Reviewed by the National Review Committee.
Approved by the Ministry of Education, (Curriculum Wing), Islamabad
Vide its letter No. F.3-2/2004-Sc. dated August 7, 2004

قومی ترانہ

پاک سَر زمین شاد باد کِشورِ حسین شاد باد
تُو نشانِ عزمِ عالی شان اَرضِ پاکستان
مرکزِ یقین شاد باد

پاک سرزمین کا نظام قُوّتِ اُخُوّتِ عوام
قوم، مُلک، سَلطنت پائندہ تابندہ باد
شاد باد منزلِ مُراد

پرچمِ سِتارہ و ہلال رہبرِ ترقّی و کمال
ترجمانِ ماضی، شانِ حال جانِ اِستقبال
سایۂ خُدائے ذُوالجلال

SERIAL No.

PUBLISHERS CODE No. 1

Date of Publication	Edition	Quantity	Price
May 2017	First	20000	122.00